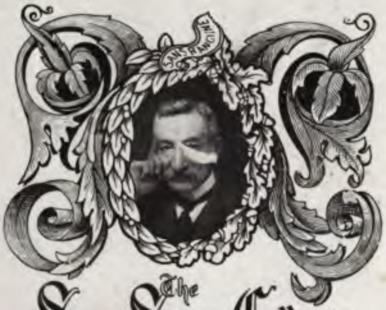

LECTURES

ON

CHEMISTRY,

WITH FAMILIAR DIRECTIONS FOR

PERFORMING EXPERIMENTS

WITH

A SMALL APPARATUS.

TO WHICH ARE ADDED,

Questions for the Examination of Scholars.

INTENDED FOR

LYCEUMS, ACADEMIES,

AND

PRIVATE STUDENTS.

BY W. G. HANAFORD, M.D.

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PREFACE.

The practice in this country of giving instruction on many subjects by Lectures, has become very common; particularly since the establishment of so many Societies for mutual improvement. It has undoubtedly its advantages, especially in what may be called the Experimental Sciences, in which that of Chemistry stands first.

But there is great difficulty, in condensing from the full and elaborate works on this science, a series of Lectures, and fitting out a course of Experiments which can be performed with a small apparatus, and in such

style and manner as shall be beneficial and interesting to persons who have paid but little attention to the subject.

Considering the great and increasing number of places where such Lectures are given, and mostly by persons who have but little time to devote to the subject, the Author has thought that he could not perform a more acceptable service than by writing out a short series of Lectures upon this subject, with familiar directions for performing experiments with a cheap apparatus; for the assistance of those who may wish to become acquainted with, or communicate to others, a knowledge of the elements of this useful and interesting science.

The arrangement which he has adopted does not materially differ from that of the large work of Brand.

He does not pretend, in this little volume, to have given an exposition of every department of this science; neither was it necessary for the object he had in view. Those who may wish to become proficients in the science, will find abundant information in most of the larger works upon this subject.

Bearing in mind what he thinks he has found, from much experience, essentially necessary in this kind of instruction, he has set aside, as much as possible, all the technical language of the science—has had but little regard to scientific or literary nicety; but has endeavoured to use a very plain, easy, and familiar style.

How far he has succeeded in his endeavours, must be left to those, into whose hands his book may chance to fall, to decide.

He has only to add, that should the sale of *this* little volume show that such a work was needed, he may possibly, hereafter, offer to the public something upon other sciences in a somewhat similar manner.

W. G. H.

Boston, September, 1831.

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the same class, by becoming acquainted with the definition of such class, we gain a certain knowledge of all the principles placed in it, with the same ease that we should any particular one, without this classification.

Very different arrangements are made by different writers. In the one which we shall adopt they are divided into four classes, and in this classification we have reference to their sensible qualities.

In the first class are what are generally called the Chemical Powers, viz. Affinity, Caloric, Electricity, and Light. They are so called, because all chemical changes are wrought upon other substances, by the application of some one of them.

Affinity, which is merely a property of matter, is placed in this class because its effects are somewhat similar to the others in the same class; i. e. it produces chemical changes.

In the second class are such substances as have the property of supporting the common process of combustion, and rendering other substances *sour*. Hence called acidifying substances and supporters of combustion. The names, Oxygen, Chlorine, Fluorine, and Iodine.

Without the presence of some one of these, it is supposed, we cannot have the common process of combustion or fire; neither can we have any substance, the taste of which is sour, in the composition of which some one of these do not form a part.

In the third class are such substances as have the property of undergoing combustion, and being rendered sour —changed into acids, by being united with some of the substances in the last mentioned class — hence called acidifying and combustible substances, not metallic.

The names — Hydrogen, Nitrogen, Sulphur, Phosphorus, Carbon, and Boron.

In the fourth class are the metallic substances, very numerous, in properties much unconnected with any of the substances in the three first classes, and as it requires much time to illustrate many of their properties, by experiment, and as a knowledge of them is of not so much use or interest to the generality of persons, but *little* notice will be taken of them in this short sketch.

AFFINITY.

Affinity, (sometimes called chemical attraction,) is that kind of attraction which unites the constituent atoms of compound substances. There are many kinds of attraction, but as we have but little to do with any except affinity in this science, it will be necessary to notice this only.

It is generally divided according to its application, into two kinds, called simple affinity and elective affinity. Also some again divided into single and double elective affinity. These terms will now be explained.

1. *Simple affinity* is that application of this kind of attraction, where two or more substances unite and form a new compound, without causing any decomposition.

ILLUSTRATION.

Mix oil, water, and potash, or oil and liquid ammonia, and they will immediately unite and form a new compound differing from any of the constituents, and yet there will be nothing thrown off from a previous state of union.

2. *Elective Affinity* is different; it is where two or more

substances unite and form a new compound, to the exclusion of some other substance, from a previous state of union.

ILLUSTRATION.

Put into a retort, a small quantity of pearlash, chalk, or marble. (The first of these is composed of *carbonic acid* and potash; the two last of the *same acid* and lime.) Turn into the retort a small quantity of sulphuric acid, diluted with *ten* times its volume of water. There will be an immediate effervescence; carbonic acid will be given off in great quantities, and may be collected as directed hereafter.

EXPLANATION.

The lime or potash has a stronger attraction for the sulphuric acid, which is an extremely strong acid, than it has for the carbonic acid, which is very weak; it *elects* it therefore,* unites with it, and forms the new compound, (sulphate of potash or lime) to the exclusion of the carbonic acid, which was in a previous state of union.

3. When substances unite by this kind of attraction, i. e. affinity, their properties and sensible qualities are frequently very much changed.

ILLUSTRATION.

Take a small quantity of muriatic acid in a glass, and put into it carbonate of soda as long as there is any effervescence. The result will be a solution of common table salt.

The muriatic acid is extremely sour and corrosive, so much so that it would take but a small quantity to destroy life, if taken into the stomach.

* Hence the term, elective affinity.

The soda also has energetic properties, in taste much like common pearlash; yet when they unite by this kind of attraction, the properties of both are changed, the acid loses all its acid properties, the alkali its peculiar properties, and this comparatively inert substance, common salt, is the result.

The salt is composed of muriatic acid and soda, (the proper name of it, *muriate* of soda,) and here these directly unite and form it.

LECTURE II.

CALORIC.

Caloric is the matter producing heat, not heat itself; thus, when we put the hand near any warm substance, we feel a particular sensation. That sensation is termed heat or warmth; it is supposed to be caused by caloric which is thrown off, or passes from the warmer substance, and enters the hand; and by its action upon it, produces this sensation. Cold is merely a negative quality, signifying only the absence or diminution of caloric; thus, when we feel the sensation of coldness, caloric passes from us into surrounding substances, and the more rapidly it passes, the more exquisite the sensation.

Though caloric is the matter producing heat, yet it can exist under certain circumstances, in such a state as to lose this property; it is then called combined caloric,

sometimes latent heat. These terms both mean the same thing; i. e. that state of that principle which under ordinary circumstances, will affect the thermometer — will produce the sensation of heat—will burn—is fire. They mean that state of this principle when it has lost this property. *Combined* caloric, therefore, may be said to be that state of caloric when it will not excite the sensation of heat, or affect the thermometer. *Free* caloric, that state of the same, when it will excite the sensation of heat and affect the thermometer.

Caloric is supposed to exist in this state of combination, in union with all material substances; in the largest quantities, in aeriform bodies — substances in mechanical properties like the common-air; next to these in liquids, and least in solids. This being the case we should of course infer that if we took any substance in an *aeriform* state, and changed it from that state to that of a *liquid*, or a liquid into that of a solid, that a portion of this caloric would be given out and become free, or that there would be an increase of temperature. Or if we took a solid substance, and changed it into a liquid, or a liquid into an aeriform body; that a portion of it would be absorbed, and that (other circumstances being equal) there would be a *decrease* of temperature; which is the case as we shall see by reference to experiments hereafter.

4. That it does exist in this state, and that it can be brought from this to that of free caloric — from that state in which it will not excite the sensation of heat, nor affect the thermometer to that state in which it will do both, may be seen by reference to some experiments.

If what has been said is correct, it of course exists in this state in common air; and that it does exist in this

state, and that it can be brought from this to a free state, simply by compression, may be seen by means of what is called a fire syringe. A metallic tube, made tight at one end, the other end left open ; into this is inserted a piston, which plays perfectly air tight; upon the end of this piston is a small quantity of tinder ; which may be prepared by wetting cotton wool in a strong solution of nitrate of potash (common salt petre) and afterwards thoroughly drying it, or what answers equally well, a small piece of phosphorus wrapped in cotton wool. By forcibly pressing this piston down, the tinder will be inflamed. The reason is this: here the air is very much compressed; the air which filled the whole of the tube being compressed into a very small space at the bottom, it is of course rendered more dense; more nearly resembles a solid, than it did before being compressed; in consequence of this, less caloric is needed in this state of combination; a part of it is pressed out and becomes free, and when free, it produces the same effect as caloric radiated from combustion ; i. e. it inflames the tinder.

5. That it exists in liquids, in this state, and that it can be brought to a free state upon the same principle, may be shown by mixing liquids which have a strong attraction for each other.

ILLUSTRATION.

Take two wine glasses, *one* half filled with water, the *other* with oil of vitriol, both *cold;* mix the liquids, and the temperature will immediately rise to nearly or quite the boiling point. All the caloric, however, which thus raises the temperature, existed in the liquids before they were mixed in a state of combination ; but when mixed, in consequence of their great attraction for each other,

they become more dense, and a portion is pressed out and becomes free.

That they do become more dense, may be known by the fact that they occupy a less space after being mixed than before: i. e. take any two measures, one of oil of vitriol and the other water, say a glass of each, mix them and they will not make *twice* as much; i. e. a *gill.*

6. The same principle holds good when liquids are changed into solids, and *vice versa.*

ILLUSTRATION.

Put water on unslaked lime, and much heat will be given out, as the lime undergoes the process of slaking

Here, a portion of the water becomes solid, and gives out its combined caloric.

That the water does become solid, may be ascertained by weighing the lime, *before* and *after* slaking, not allowing any thing to come in contact with it, but the water, and yet it will be found to increase in weight during the process; as all we have after it is slaked, is perfectly dry and solid; and as it weighs more than before, it of course shows that a portion of the water must have become solid.

7. When solids become liquids, and when liquids become aeriform bodies, there is (owing to the same principle) a decrease of temperature. For, as it requires a larger quantity of caloric, in this state of combination, to keep any substance in a *liquid* state than it does to allow it to exist in a solid state; and also to keep any substance in a gaseous or aeriform state than in that of a liquid, whenever these changes take place, caloric is taken from surrounding bodies unites with them, and loses the property of exciting the sensation of heat, and of course in the vicinity the temperature is lowered.

ILLUSTRATION.

Mix snow and salt in a small vessel, and stir the mixture with a thin, small vial, having in it a small quantity of water; while the *solid* snow and salt are melting the water in the vial will *freeze;* illustrating the fact, that when solids become liquids, there is a decrease of temperature.

ILLUSTRATION II.

Put on the bulb of a large air thermometer, a small quantity of sulphuric ether, boiling hot. (The ether may be heated by warming a wine glass and turning the ether into it.) Although the ether is thus hot, it will produce the same effect on the thermometer as ice; for in consequence of the rapid evaporation, i. e. the change from the liquid to the aeriform state; much caloric must unite with it, and lose the property of exciting the sensation of heat.

The air thermometer may be made by taking a bolthead, having a long, slim neck; warm it a little, and place the end of it in a decanter, partly filled with any colored liquid; as it cools the liquid will rise in the neck.

It is on this principle, that sprinkling the floor of a room in hot weather, or wrapping bottles of wine or cider with a wet cloth, will tend to decrease the temperature. Also the paradoxical experiments of freezing persons, by turning boiling hot ether upon them, keeping them in a hot place.

As has already been stated, we must examine the substances in this class, by noticing the effect which they produce upon other substances, as they cannot be confined and submitted to the usual method of examination.

We may, therefore, in the next place, refer to some of the effects which caloric produces upon other substances; and first may be illustrated this fact.

PROPOSITION.

8. More caloric is required to cause any liquid to bc when the surface of such liquid is exposed to the pressu of the air, than if this pressure, or any part of it, is ı moved.

ILLUSTRATION.

Fill a Florence flask one third full of water. Fit sound cork to the mouth of it, so that it will make it pe fectly tight, leaving the stopper out, place the flask ov a spirit lamp and allow it to boil. Then remove the he and *immediately* make the mouth of it tight. Then l turning cold water, or putting ice upon the outside, will cause the liquid in the vessel to boil rapidly.

The reason is this, when the water boiled in the fi place, a part of it was converted into vapor, its volun being increased, it drove out the atmospheric air whi filled the upper part of the vessel, so that when the co was inserted, the upper part of the vessel was filled wi the vapor of water. Cooling this condenses it, brings back to the state of water again, and causes it to occu a less space; but as the mouth of the flask is tight, a cannot come in to press upon the surface of the wat and this is the reason why the water boils at so low temperature.

When perfectly freed from the pressure of the ai water will boil at a temperature of 67 deg. of Fahre heit's thermometer, the one generally used in this cou try; i. e. it will boil at a temperature much below tl temperature of the body.

Air presses with a force equal to about fourtee pounds upon every square inch of surface exposed to i That it does press with some force upon surfaces expose

to it, may be seen by the very simple experiment of putting over the mouth of a small vessel containing water, a piece of thick paper, holding it on with the hand till the vessel is inverted, the pressure of the air against the paper will support the water in the glass. The reason is, that the paper is yielding, so that the air through the medium of the paper can press upon the under surface of the water, but the glass not being yielding, it cannot press with equal force upon the upper surface.

LECTURE III.

CONTINUATION OF CALORIC.

One of the most obvious and familiar effects of caloric is that it has a tendency to expand all substances; i. e. heat any substance, and it is expanded, and occupies a larger space, cool it and it is contracted, and occupies a less *space.* There are one or two exceptions to this very general principle, which will be noticed hereafter.

9. We might take as a proposition, therefore, that all substances are expanded by being heated. We cannot of course, illustrate this to the fullest extent, because, to do it, we should have to refer to the effects which caloric would produce upon all substances. We may select substances, therefore, from the three large classes of natural

another mark. Then divide the space on the tube, between these two marks, into an equal number of degrees, and extend degrees, of the same length, above and below these marks: and we shall at once perceive, that these will be the properties of this instrument. Whenever it is exposed to a temperature, just as cold as at which water will freeze, the liquid in it will be just as much condensed, as it was when put in the freezing water in the first place: and whenever exposed to a temperature, just as high as at which water will boil, it will be just as much expanded, and the liquid in the tube will stand at the same place; and so on with any intermediate temperature, above or below these marks.

12. That solids are expanded, by being heated, may be seen, by taking the measure of a metallic rod when cold, heat it and we shall find it longer.

ILLUSTRATION II.

This fact is illustrated more plainly, by using a pyrometer; which is a machine so constructed, by means of a multiplying power, that a slight expansion of a bar of metal, or any other substance, may be seen on a large scale.

Place a rod in the pyrometer, and apply heat to it; it will cause the index to move over a large surface.

It is owing to this principle, that it is so extremely difficult to obtain clocks and watches that shall keep correct time; for when heated the different parts are expanded, and move slower—will lose time: when colder will be contracted—move quicker, and of course gain time.

13. Caloric tends to an equilibrium, i. e. passes from

one body if hot, to all other bodies in the vicinity, till they are of the same temperature.

We may see this in part illustrated, by putting the hand upon the bulb of the air thermometer. At first the liquid will descend, but soon become stationary. The hand being warmer than the air within the thermometer, caloric passes from the hand to the air, warms and expands it, until that becomes of the same temperature. All bodies similarly situated for any considerable length of time, will be of the same temperature.

14. Bodies have the property of conducting caloric, or allowing it to pass through their substance. Different substances possess this property, however, in very different degrees.

ILLUSTRATION.

This may be illustrated by taking small cones of different substances, a few inches long, and putting a little wax or phosphorus on the apex, set them on a heated metallic plate. The wax will be melted, or the phosphorus inflamed, from some much quicker than from others. It may also be illustrated, by the conductometer, which is a small tin vessel, about two inches in height, having a number of tubes in the top of it. Fill this with hot water, and place in these tubes rods of different metals, glass, pipe-clay, wood, &c. having the wax or phosphorus on the upper end as before. The difference in time, in which they will be effected, will show the different conducting powers of the substances.

All metallic substances are good conductors, though some are better than others. Silver, gold, and cop-

per, are better conductors than platinum, iron, and lead. Wood charcoal, wool, silk, feathers, down, fur, &c. are poor conductors. This principle has a wide application in domestic economy.

15. Caloric is reflected from hard polished surfaces like light.

ILLUSTRATION.

This may best be illustrated, by using two concave mirrors, of planished tin or plated copper, placed at the distance of about eight feet. Under these circumstances, when a thermometer is in the focus of one of the mirrors, it will be found to be effected by a heated body placed in the focus of the other: and that it is produced by reflection, and not radiation, may be shown by moving the thermometer out of the focus, towards the heated body, or by hanging a small screen between the thermometer and heated substance; in neither of which cases will the thermometer be effected.

Having a ball two inches in diameter, heated red hot, in the focus of one, place a lamp so that the wick shall be in the focus of the other. A small piece of phosphorus, placed in the wick, will be inflamed and light the lamp.

16. When liquids are changed into aeriform bodies, they are immensely expanded.

ILLUSTRATION.

This may be illustrated in a very amusing way, by using an *eolipile*, which is a globular piece of metal, or glass, having a long slim neck. It may be used by the following method. First heat it and expand the air: then hold the stem in cold ether or alcohol:

as the air is condensed, the liquid will be forced into it. Then hold the ball over a lamp and cause the liquid to boil: as it is changed from the liquid to the aeriform state, it will be expanded and forced through the tube with great velocity: which may be seen by applying a blaze to the vapor; it will burn brilliantly. By causing it to boil rapidly, a stream of blaze many feet long will be produced.

LECTURE IV.

ELECTRICITY.

The word Electricity, comes from the Greek word *electron;* which is the name of the substance we call *amber.* It happened to receive this name, from the circumstance that electrical phenomena were first discovered, by using that substance; and at that time was thought to be a property peculiar to that substance only. Since, however, most other substances have been found to possess the same property, under certain circumstances.

Electricity is one of those subjects, in which the progress of ascertaining its nature and properties, has been very slow. For although some of its properties were known, even many centuries before the Christian era, it is altogether probable that its most useful properties

are yet to be discovered. By Franklin's discovery, i. e. that it was the same as lightning, we might say that it was, to a certain extent, rendered harmless to mankind; but it would appear, that another Franklinean discovery was necessary, in order to render it of much use.

In this subject, we have one different from almost any other, with which we have anything to do, either in this science, or experimental philosophy. Such is the fact, that almost all the principles, in the experimental sciences, can be so satisfactorily illustrated, as to leave no doubt in regard to their correctness. Not so with this; it is extremely difficult by any direct experiments, to prove what it is, or much in regard to its properties. This being the case, there have been very many different theories upon this subject; some considering it a simple substance; others supposing that there are two fluids, called vitreous and resinous; others that it is merely a property of matter. To explain all these different theories, would require much time. I shall, therefore, entirely omit it; but shall select that *theory*, which is usually adopted in this country, and which appears to have as much evidence in favour of its being correct, as any; and explain the principles of the science, and the few experiments to which we may be able to refer, according to this theory. It has at least some things to recommend it; for upon this theory, the principles of the science are more simple, more easily explained and applied to useful purposes, than perhaps any other.

The theory to which I refer, is generally called the Franklinean theory. Not because it was first adopt-

ed by our own countryman Dr. Franklin, but because he supposed it correct, and very much improved the science in this belief.

The theory is this : there is supposed to exist in nature, an extremely subtle fluid, called electricity, which is supposed to pervade all material substances. No substance whatever is supposed to be entirely destitute of it. This small quantity, which all bodies are supposed to contain, is called their *natural share* ; and so long as any body contains neither more nor less than this, it does not *seem* to produce any effect. But if from any circumstance whatever, any body is caused to contain either more or less than this quantity, which they always contain, then it does produce some effect. When a body contains more than its natural share, it is called *positively* electrified ; and when less, *negatively* electrified.

There are very many methods by which this fluid may be excited ; i. e. by which some substances can be made to contain *more* or *less* than they ordinarily do. Friction is one, and on this principle the electric machine is constructed. The evaporation or condensation of any liquid, is another ; and on this principle it is supposed to be excited on the immensely large scale, as we have it in the lightning. There are also other methods.

Before we mention anything further, in regard to this subject, it may be well to illustrate a few of the principles of this science by reference to experiments.

PROPOSITION.

17. Bodies similarly electrified, repel each other ; but when dissimilarly electrified, attract each other.

i. e. Bring two bodies near each other, *both* of whi(contain, either more or less of this fluid than their n tural share, and they will have a tendency to separat But bring two bodies near, one of which contains mo than its natural share, and it will be attracted by eve body which contains *less* than that does ; if it contai less than its natural share, it will have a tendency be attracted by every body which contains more th that does.

ILLUSTRATION.

Suspend some light pith balls, by *cotton* thread from the main conductor of the electric machin Turn the machine, and they will separate ; i. e. bot being positively electrified, as well as that part of th machine from which they are suspended, they ar repelled by the conductor and by each other.

18. Experiment 2d. Suspend a pith ball from th prime conductor, by a silk thread ; charge a Leyde vial, and bring the knob of it near the ball. It wi for a moment be attracted, but afterwards repelled The brass knob being *positively* electrified, and th pith ball being in its natural state, they are of cours *dissimilarly* electrified, and will therefore be attracted but the pith ball being suspended by the silk thread which is a non-conductor, soon receives electricit from the brass knob ; so that soon they become simi larly electrified, and then are repelled by each other Touch the pith ball with the hand, or any other goo conductor, and the electricity will be taken from it and then the brass knob will *attract* it as before.

19. Some bodies have the property of attracting this fluid, and allowing it to pass through their sub-

stance, called *conductors*. Others have not this property, and are called *non-conductors*.

ILLUSTRATION.

Having turned the machine, bring near the prime conductor any *metallic* substance. The electricity will pass from the conductor, on to it ; and we shall notice a slight snapping noise ; and the pith balls, suspended by the cotton threads, will fall down, indicating that the electricity has passed off. Afterwards, bring a piece of glass in the same situation ; the effect will be different. In the first place, we shall not hear the slight report as before ; neither will the pith balls fall down : showing that the glass does not take the fluid off ; i. e. the metallic substance attracts the electricity, and allows it to pass through its substance to the floor, &c.—hence called a conductor. The glass has, neither the property of attracting the electricity, or allowing it to pass through its substance ; and therefore, called a non-conductor. The metals are all good conductors. Dry air, glass, sulphur, silk and resins, are non-conductors. Water, damp wood, damp air, spirits, and some kinds of oil, are imperfect conductors.

20. Sharp metallic points will attract this fluid further and very differently from larger surfaces. Excite the fluid by turning the machine. Then bring near the prime conductor the ball of the discharger, having a chain passing from the handle, and touching the outside of a Leyden jar connected with the machine. An electric spark will pass on to it, with a slight report, and at the same time the pith balls will *immediately* fall down : showing that the fluid is all taken off

at once. Again excite the fluid as before; then instead of presenting the large surface, bring gradually near it a sharp metallic point. The effect will be different; we shall hear no report; shall see no spark, and yet the pith balls will *gradually* fall: showing that the fluid is taken off. When the point is brought near, the electricity commences passing on to it, but different from what is the case when the large surface is presented; it is attracted some distance, continually and gradually, producing no visible effect: whereas when the large surface is presented, none of it will pass off till it is brought quite near, and when it commences, it all passes off at once.

On this principle (as will hereafter be explained) depends the utility of the common Lightning Rod.

Having illustrated these few principles of the science, we may now with propriety explain the common Electric Machine.

It has already been stated, that one method of exciting this fluid, was *friction*. It depends, however, upon this circumstance, the rubbing together of two substances, one of which is a good, and the other a bad conductor of this fluid. What is meant by these terms, has already been explained. The common machine is constructed upon this principle, and here it may be premised that the *shape* is immaterial; and that very many different substances will answer the purpose. The principle being, as has been stated, only that friction is produced between two substances which differ much in regard to conducting this fluid. Glass, and some metallic substance, are what are generally used. The *shape* of the glass is generally that

of a cylinder, or plate; and the metallic substance, an amalgam of mercury, with tin or zinc.

OBSERVATION.

The best method of making this amalgam, is to take any quantity of mercury, and put into it common tin foil, or block tin, in small pieces, until the mixture is of the consistence of a thick paste. It will take some time for the mercury to dissolve the tin.

This amalgam is generally spread upon an elastic cushion; which is attached to a spring, so arranged, that the cushion may press firmly upon the glass. Turn the glass, and friction is produced between the bad conductor, the glass, and the good conductor, the metallic substance. When this is done, electricity is taken from the good conductor, and accumulated upon the bad; i. e. is taken from the amalgam, the cushion, &c., and accumulated upon the glass—is retained upon the glass, by the flap of silk, (which is a bad conductor,) till it comes round to the prime conductor of the machine. Projecting from this, and coming near the glass, are a number of *sharp points*: as we have already seen, sharp points will *attract* electricity some distance; as quick, therefore, as any of the fluid comes near these points, they immediately attract it. These points, as well as the prime conductor, being metallic, are good conductors: therefore, as quick as any of the fluid touches the points, it is immediately diffused over the whole metallic surface connected with them. But in consequence of the conductor's standing on glass (a non-conductor), the fluid cannot pass through that to the table; and if the machine is surrounded with a dry atmosphere, that is a non-conductor, and also

prevents its escape ; so that the electricity is retained, in a larger quantity than its natural share, on the conductor, i. e. it is positively electrified.

To produce electrical effects, we have only to allow the fluid, thus accumulated on this part of the machine, to pass through the body to be operated upon. When it passes through the living system, it produces the electric shock. Allow it to pass on to many combustible substances, such as warm alcohol, gunpowder, a mixture of oxygen and hydrogen gases, &c., and they will be inflamed.

It has been mentioned that lightning and electricity were the same. It may be well enough to mention the method by which Franklin ascertained this to be the case. He caused a common boy's kite to ascend in the air, during a thunder storm, having the string made of some conducting substance, and sharp metallic points projecting from different parts of the kite. He held this, by having the string attached to a glass rod, to prevent the fluid passing to the hand ; and having tied to the end of the string, a key or metallic ball. When thus elevated, the points projecting from the kite, attracted the lightning from the passing clouds ; it passed down the string, and he found that from the key or ball at the end of it, the same effects might be produced as could with the electric machine : that he could charge Leyden vials—give the electric shock—could perform all the experiments, and exactly in the same way, as he could with the machine. He of course came to the conclusion that lightning, and electricity as collected by the machine, were the same.

Lightning and electricity being the same, they are of course governed by the same laws.

A knowledge of this fact may be of utility as it regards our own safety in a thunder storm. We have already seen that some substances conducted this fluid much better than others. There is no doubt that we are more exposed to injury, from the effect of lightning, in some situations than others. The principle necessary to bear in mind, is this—that we surround ourselves with as poor conductors of this fluid as possible. If we could be surrounded with glass, probably we should be perfectly safe. Standing upon a stool with glass legs would be a safe place, but such situations are not often at command. I might, therefore, refer to some situations which may generally be selected by any one, and which are tolerably safe. Sitting in a chair in the middle of a room, with the feet placed on the rounds—or upon a bed placed in the same situation, more particularly if the floor is covered with a woollen carpet, are safe, comparatively speaking. The reason is this—if the house was struck with lightning, it would be less likely to pass through these bad conductors—the woollen carpet, the dry wood—i. e. the supporters of the bed or chair—and reach us, so situated, than it would to take some other course.

We should *not* be near the outside of a room, particularly if the walls are wet. Wet wood is a conductor. Nor near any large or long metallic substance, such as a bell wire, stove, &c. ; nor near a chimney—nor in a room where the floor is wet. I do not mean to say that in any of these situations we are

perfectly safe ; but only that, calculating the chances, we may be more safe than in other situations.

While explaining the machine, it was stated, that sharp points would attract this fluid further, and differently, from larger surfaces.

Upon this principle, depends the utility of lightning rods. There is no doubt, that if rightly constructed, these rods may be of much utility—abundantly sufficient to pay the expense of erecting them ; though they may be so—they frequently are so arranged, that instead of being a safeguard from the effects of lightning, the building on which they are placed is more likely to be injured than if they were far from it.

I will mention the method in which those who are well qualified to decide, and who have paid much attention to the subject, give directions for arranging them.

They should ascend high above the building—should terminate in sharp points ; the ends of which should be *tipped* with some metal that will not easily rust,—tin or silver is generally used. Should be sufficiently large that there will be no danger of their being melted ; say from three fourths of an inch to an inch in diameter, of copper or iron. Should not be fastened to the building by *metallic* substances ; glass is the best, though wood answers very well. Should not touch or come near any large pieces of metal, attached to, or in the building. Where the different parts of the rod are joined together, they should be so arranged, as to touch on a large surface, and firmly. Should descend so deep in the ground, that we may be sure that the lower end is always where the

earth is moist. It is well to let the lower end be buried in a wet place; as under the spout of a sink, or pass into a well, &c.

LECTURE V.

LIGHT.

Light is another of those substances, which from its effects, we must learn most of its properties. Like electricity and caloric, it is of so subtle a nature, as to require minute and delicate investigation, to demonstrate its existence. Like them it can neither be confined, nor submitted to the usual modes of examination; and is known only in its state of motion, as acting upon our senses, or as producing changes in the more gross forms of matter. Numerous opinions have been formed concerning this substance. By some it has been considered as a quality, by others as a cause, and by many as an effect. By some it has been considered as a compound—by others as a simple substance.

Among the ancients, it was thought that the sensation which we receive from light, was to be attributed entirely to the vibration of a subtle medium, or fluid, which was diffused throughout the whole universe,

and which was put in action by the influence of the sun. In this view, they considered light as analogous to sound, which depends upon the vibrations of the particles of matter through which it passes. To this opinion, however, there are many weighty objections.— 1st, the velocity of sound bears but a small proportion to that of light. Light travels, in *eight minutes*, a distance which sound could not be communicated in less than *seventeen years* : and 2dly, if light depended altogether on the vibrations of a fluid, which was put in action by the influence of the sun, there is no solid reason why this fluid should cease to vibrate in the night ; since the sun must always affect some part of the circumambient air ; and thus produce an endless day ;—and thirdly, if this was the case, we could as well see through a bended tube as hear through one.

But among the many improvements and discoveries that have been made on different subjects by the moderns, light has come in for a share ; and by them it is almost universally admitted, that light consists of an infinite number of extremely minute particles, which are actually projected from the luminous body ; and that in order to produce the sensation of sight, they must be transmitted to the *retina* of the eye.

In regard to the properties of light, what would first strike our attention, perhaps, would be its amazing velocity. In the short time of one second, a particle of light traverses an extent of more than 180,000 miles, which is so much swifter than the progress of a cannon ball, that light passes a space in eight *minutes*, which could not be passed, at the ordinary velocity of a cannon ball, in less than thirty-two *years*.

It is also ascertained that the velocity of light is uniform ; whether original, as from the sun, or reflected from any other body.

The rarity of light, and the minuteness of its particles, are not less remarkable than its velocity. If, indeed, the particles were not almost infinitely small, their excessive velocity would render them destructive in the highest degree. It has been demonstrated, that light moves about two millions of times swifter than a cannon ball. The force with which moving bodies strike, is in proportion to the quantity of matter, multiplied by the velocity ; and consequently, if the particles of light were equal in bulk to the two millionth part of grains of the finest sand, we should no more be able to bear their impulse, than that of sand, shot, *point blank*, from the mouth of the cannon.

The minuteness of the particles of light, is also demonstrable, from the facility with which they penetrate glass and other solid bodies which have their pores in a rectilinear or straight direction ; and that without the smallest diminution of velocity.

Bodies which intercept the rays of light, are called opake, and when rays of light are impinged, or strike upon such surfaces, they are thrown back towards their source, or reflected. Light is, therefore, elastic, and its elasticity is perfect ; for the angle formed with a perpendicular to the surface, by the reflected ray, is always equal to that formed by the incident ray—i. e. the angle of reflection is equal to the angle of incidence.

The elasticity of any substance is said to be perfect, if, when it falls upon any substance, it is thrown

back, or rebounded, with the same force and velocity that it had when it struck. Light is not homogeneous, i. e. its particles are not all alike ; they differ in colour, and also in refrangibility. It may be separated by the prism into seven parts, which have different colours ; viz. red, orange, yellow, green, blue, indigo, and violet. Red is the least and violet the most refrangible. The violet ray of light, has the property of imparting the magnetic property to steel. It may be done in the following way. By the prism, intercept all the rays except the violet, and having collected them in a focus, by a lens, throw it on a common needle, and carry it to the extremity. This must be repeated several times, and always towards the *same* extremity ; after some time the needle becomes magnetic.

Light is considered as constituting an important part of all inflammable substances. In every instance of combustion, light is disengaged.

Examples have been adduced, to prove that light depends on the combustible body. The colour of the light emitted, is peculiar to the body burned ; this would hardly happen unless the light *depended* on it ; as the oxide of copper exhibits a green light, indigo blue, hydrogen a greenish blue, sulphur a pale blue, phosphorus a white, &c.

Bodies which possess the property of emitting light either spontaneously or by combustion, so as not to decompose them, are called *phosphorescent*.

Many chemical compounds possess this property in an eminent degree. In some cases it is excited by heat, or by the solar *ray* ; in others spontaneously, as

in dead animal and vegetable substances ; in the latter it probably owes this property to incipient or beginning decomposition. By putting pieces of some kinds of fish into *salt* water, and keeping them in the dark a few days, they will become luminous.

The light emitted from animal and vegetable substances in a state of decomposition, produces no effect on the most delicate thermometer ; hence it is inferred that light constitutes a component part of these substances, and that it is the first which is extricated, when the substance containing it is beginning to be decomposed ; or when the putrefactive fermentation commences.

Some *living* animals possess the phosphorescent property ; the glow worm and firefly, or lightning bug as it is generally called, are examples of this kind.

The chemical agency of light is very striking in many of its effects. The beauty of colour, and fragrance of vegetables, appear to depend on it entirely, and it has an influence even on their health and vigour If light be excluded from a growing vegetable, for any length of time, it shoots out rapidly at first, seeming, as has been observed, in quest of its great supporter ; but if denied it, it turns pale, sickens, and dies.

It is a well known fact, that plants, growing under shelter, will turn the ends of their branches to that quarter from which the light comes, be it in whatever direction it may.

Plants, which grow in the shade, lose in a great measure their inflammability ; hence, light seems necessary to the very existence of combustible bodies.

The different sources from which it is emitted, in visible form, are *three*, viz. from the sun and fixed stars—combustion—and when bodies become luminous in consequence of being heated; and it is found that all bodies that are capable of enduring the requisite degree of heat without volatilization, begin to emit light at the same temperature.

Light brings into use the organs of vision, and is the proximate cause of the sense of sight: and although invisible itself, by its influence on other matter, it imprints their image on the sensible retina of the eye, prepared for their reception, and in that way excites the sensation of sight; which, as has justly been observed, renders more pleasure to the mind than all the other senses.

It is a very powerful agent in nature. Its general effect on animals is to render them of a darker and more vivid colour. Vegetables it renders darker, more sapid, and of a stronger consistency; and by its effects on the differently arranged particles of matter, causes what we call colour.

Most of the properties of light come properly under the head of experimental philosophy, not *this* science. A few, however, belong to chemistry. The greater part of the experiments to which we may be able to refer under this head, have regard to colour—what might be called the *philosophy* of colour. Colour is not an inherent property of the different substances upon which we look, but exists in the light. In the light there are seven different colours, viz. red, orange, yellow, green, blue, indigo and violet:

and on these seven colours in the light, depend the colour of all substances. The substances upon which we look, simply having the property of reflecting or absorbing one or more of the different colours in the light; i. e. when a substance appears *red*, it is because it has the property, when the light strikes upon it, in which light are these seven colours, of reflecting the *red* part of the light, and not the other colours: and when it appears of any other colour, then that particular colour, of which it appears, is reflected, and not the rest.

These are supposed to be the only primary colours in nature; and when any substance appears of any other colour than these (excepting white or black), it is because two or more of these colours are reflected at the same time, thus modifying the colour.

There are many methods by which this may be illustrated. The one best adapted to answer the purpose, in this science, is by mixing liquids which are transparent, or nearly so, and noticing the changes in the colours.

Prepare the following liquids:—1. Infusion of red cabbage or blue violets. 2. Corrosive sublimate.* 3. Lime.* 4. Pearlash.* 5. Copperas.* 6. Prussiate of potash.* 7. Verdigris.* 8. Liquid ammonia. 9. Nutgalls. 10. Oil of vitriol coloured black by putting any kind of wood in it.

These liquids are all very nearly transparent; but mix them in the following order, and the following colours will be produced.

* Solution of these in water.

1 and 10 mixed, will be red; 2 and 3, orange; 3 and 4, yellow; mix the blue and yellow and it will be green; 7 and 8, blue; 5 and 6, indigo; mix the red and blue to make the violet.

Here, as all these liquids are nearly transparent before they are mixed, and as they appear of very different colours afterwards, though their other properties are not changed, it of course goes to show that colour depends upon the *arrangement* of the particles of substances, but is not an inherent property possessed by them.

For example: in mixing the lime water and corrosive sublimate to produce the orange, the liquids before being mixed are perfectly transparent; i. e. light passes easily through them, and we can therefore see through them. But when mixed, the particles are differently arranged; so arranged, that when the light strikes upon the liquid, in which light are the seven different colours which have been named, all the colours except the orange coloured rays are absorbed by the liquid; the orange coloured part of the light only being thrown off and coming to the eye, gives us the sensation that the substance itself, from which the light comes, is of that colour.

The same principle may be more plainly illustrated by adding a small quantity of the coloured oil of vitriol to the orange colour; they will both immediately become perfectly transparent.

The principle holds good when substances appear of any other colour; i. e. if they appear *red*, then the *red* part of the light is reflected, and not the others; if blue, then the blue part of the light, and so on.

When a substance appears of any other than one of these seven elementary colours, except white or black, it is because two or more of these colours are reflected at the same time, thus modifying the colour.

When a substance appears black, all the rays of light are supposed to be absorbed by it. When white, they are all supposed to be equally and at the same time reflected from it.

Black may be obtained for the purposes of experiment, by mixing a solution of copperas and nutgalls, which gives us common writing ink. The colour of that can be entirely removed by adding oil of vitriol. And if we use the coloured acid, we shall have the curious fact of two perfectly black liquids becoming transparent simply by being mixed.

White may be obtained by mixing a solution of sugar of lead and pearlash.

LECTURE VI.

CLASS II.

Acidifiable Substances and Supporters of Combustion.

GENERAL OBSERVATIONS.

In this class are such substances as have the property of supporting the common process of combus-

tion, and of rendering certain other substances sour; hence called acidifying substances and supporters of combustion. There are four, viz. Oxygen, Chlorine, Fluorine and Iodine.

Before referring to the properties of these substances, it may be well to give some idea of the principle which has been adopted for naming the different compound substances in this science. This principle is called the *new* nomenclature.

When any of the acidifiable substances have united with each other, with any of the substances in the third class, or metallic substances, and the compound is not sour—does not possess any acid properties, the name of the compound *ends* in *ide*, and is called an oxide, chloride, &c. If it is sour, or possesses acid properties, it is called an *acid*. Oxygen, with sulphur, will give us the oxide of sulphur; with iron, the oxide of iron. The *proportions* of oxygen are expressed by prefixing contractions of three of the Greek numerals, signifying once, twice, thrice, i. e. *Prot.* from Protos, *Dut.* from Dutos, and *Trit.* from Tritos; together with the Latin preposition *per*, signifying through, and is to be understood thus.

One proportion of oxygen with any substance will be the Protoxide. Two proportions, or twice as much, would be the Deutoxide. Three, the Tritoxide.

The Peroxide is intended to represent the highest proportion of oxygen; or in other words, that that particular substance has united with the greatest quantity of oxygen that it can be made to unite with.

The *proportion* of oxygen in the acids is expressed by the termination in *ous* and *ic*.

Whenever any substance has united with oxygen and formed an acid, if it is not the strongest acid that can be formed by uniting that *particular* substance with oxygen, the name of it ends in the letters *ous* ; if it is the strongest, it ends in the letters *ic*. EXAMPLE. Sulphur, allowed to burn in the air, forms an acid, but it is not the strongest acid that can be formed by uniting sulphur with oxygen. It is, therefore, called the sulphur*ous* acid. But if we allow the sulphur to burn in pure oxygen gas, or mix with it some substance which will give off oxygen as it burns, say saltpetre, it will then unite with a larger quantity of oxygen, and form a stronger acid—the strongest that can be formed by uniting sulphur with oxygen—and is the sulphur*ic* acid, or oil of vitriol.

Thus we find that the names of all the strong acids end in the letters *ic*.

All of these acids can unite with all of the alkalies, earths and metallic oxides, and form what are called salts ; i. e. a salt is composed of an acid united with an alkali earth or metallic oxide.

These salts are a very numerous and important class of compounds. The following principle has been adopted for naming them. When the name of the acid ends in *ic*, the name of the salt ends in *ate*. When the name of the acid ends in *ous*, the name of the salt ends in *ite* ; i. e. *nitric* acid with soda would be the *nitrate* of soda ; *nitrous* acid would be the *nitrite*, and so on.

When any of the substances in the third class have united with any other substance in the same class, with any of the alkalies, or metals, if the compound is either

liquid or *solid*, the name of it ends in the letters *uret*. Sulphur and iron would be the sulphuret of iron. Carbon and iron would be the carburet of iron, &c. But if the compound thus formed is in a gaseous state, then instead of the letters *uret*, the letters *uretted* are added. Thus sulphur and hydrogen can be made to unite, and the compound is in a gaseous state; the name of the compound, therefore, ends in these letters, and is called the sulphuretted hydrogen. Carbon and hydrogen would be the carburetted hydrogen; and so on with the others.

OXYGEN.*

The word Oxygen is derived from two Greek words, which, when translated into our own language, signify, literally, the sour maker. It is a substance of much importance in this science. It exists in very large quantities in nature. It forms an essential part of the animal kingdom, the vegetable kingdom, of air, and water. It also exists in large quantities united with mineral substances. There cannot exist any living animal, or vegetable, common atmospheric air, or water, unless this is present; as it forms an essential part of all; and of many of them, a large part. It has also the property of uniting with a greater number of other substances, and with the same substances in a greater number of *proportions*, than any of the other simple substances. The compounds which it thus forms are of much importance. Almost

* Formerly called *Pure Air*.

all substances which have striking or energetic properties, contain it; such as the strong acids, and alkalies; also most substances which are very poisonous; such as opium, corrosive sublimate, ratsbane, &c. It is not to be understood, however, that all substances which contain it, even in large quantities, are poisonous; water contains it in very large quantities.

It is generally examined in a gaseous state. In that state, it is a little heavier than atmospheric air. It may be obtained in many ways.

I will in the first place refer to a very simple method, by means of which it can be obtained, by any one, without much apparatus.

21. It is given out by growing vegetables.

ILLUSTRATION.

Take a pint tumbler, put into it a quantity of the leaves of some vegetable growing very thriftily, which should be gathered early in the morning; then fill the remaining part of the glass with water. Place over the mouth of the glass a piece of thick paper, and on that a common plate; holding this firmly on the mouth, invert the whole. Put a small quantity of water in the plate; set the whole in the direct rays of the sun, through the day. Oxygen gas will be disengaged from the leaves, ascend through the water, and remain at the upper part of the glass. If we now invert the whole, bring the tumbler upright, and remove the plate, leaving the paper upon the mouth of the glass, and afterwards carefully remove the paper from a portion of the glass, and introduce a small taper after the blaze is *blown* off, having fire on the wick, it will be *relighted*, showing that it is oxygen.

22. The method generally adopted for obtaining it in large quantities, for experimental purposes, however, is by using, either the black oxide of manganese, red lead, or nitrate of potash (common saltpetre).

ILLUSTRATION.

Take a common gun barrel, make the breech of it perfectly tight; fill it one third full of saltpetre, coarsely pulverized; connect a lead tube with the other end, by winding wetted flax or tow round the tube; then screw it firmly into the mouth of the barrel, so as to make it air tight. Place the barrel in a situation where it can be heated; allowing most of the heat, *at first*, to come on that portion of the barrel where is the *upper* portion of the materials in the barrel. When the heat is such as to make the iron nearly red hot, the gas will begin to pass off. The most convenient method of heating it, is to take a common clay furnace; make a hole in one side of it, sufficiently large to allow the barrel to pass through; put the breech of the barrel from the inside of the furnace through this, and allow the other part of the barrel to rest on the top. We may ascertain when it is sufficiently pure to collect, (the first which passes off is not pure,) by filling a small vial with it, and putting into it a taper, as has been directed heretofore; and when it will relight the taper, it will do to collect. It may be collected by the following method. Fill the vessels, in which it is to be collected, with water; invert them, and bring the open part over the tube in the moveable shelf in the pneumatic apparatus (which has been explained). The gas, as it is disengaged from the tube, will bubble through the water,

and allow the water to pass out, and mix with the water in the cistern.

We may now refer to some of its properties.

23. It will support combustion.

ILLUSTRATION.

Fill a small vessel with it, and put into it a taper as before; it will be relighted. A small piece of dry pine wood, used in the same way, will also be relighted.

24. It will support combustion much better than common air; so that many substances will burn in it, that cannot be made to burn in the air. Most of the metallic substances can be made to burn in it.

ILLUSTRATION.

Fill a quart decanter nearly full of it; attach a piece of watch spring, or a coil of iron wire, to a cork which fits the decanter; wind a thread of silk round the end of it; dip this silk in melted sulphur, having but a very small quantity of the sulphur; inflame this sulphur, and immediately put it into the decanter; the steel or iron will be inflamed, and burn with rapidity, throwing off beautifully bright scintillations, and continue to burn as long as there is a sufficient quantity of oxygen.

25. Oxygen makes certain other substances sour, by being united with them in certain proportions, and under certain circumstances. Generally, though not always, it unites with these substances by means of combustion.

ILLUSTRATION.

Fill a decanter nearly full with it. Take a piece of tin, one fourth of an inch wide, and long enough to

reach to within an inch of the bottom of the decanter. Fix it to a cork which fits the decanter; bend up the lower end of it, and place on it a small piece of sulphur; inflame the sulphur, and, while burning, place it in the decanter; it will continue to burn. The solid sulphur will disappear, and instead of it we shall find a dense white vapor filling the decanter; which is the union of the sulphur and the oxygen, and is a strong acid. It will be taken up by the water at the bottom of the vessel, and render that sour; which may be ascertained by the taste or by any other test.

ILLUSTRATION II.

26. Fill a decanter, and fix a piece of tin and cork as before, with this exception. Make a small hole through the *cork*; through which a small wire can be passed. Place on the end of the tin a small piece of phosphorus. Heat a wire and pass it through the aperture in the cork; so as to bring it in contact with the phosphorus. It will be inflamed, and burn with extreme brilliancy, giving out a very great quantity of heat and light, and probably break the vessel. The phosphorus will here be rendered sour, as was the sulphur in the other case. The acid will first appear in the form of a dense, white vapour, which will be afterwards taken up by the water, and render it sour.

By this experiment, we see illustrated still further the fact, that oxygen is a good supporter of combustion; also the extreme inflammability of the phosphorus.

27. Oxygen is the only supporter of combustion in the common air.

ILLUSTRATION.

Fill an eight ounce vial with nitrogen gas, (in the

manner as explained under the head of nitrogen,) which with oxygen forms common air, and by putting a small candle into it, while burning, we shall see that it will not support combustion. Then turn from the vial one-fifth part of the nitrogen, by letting in water, and then fill the remaining part of the vessel with oxygen. By again putting a taper into it as before, we shall find that it will burn. As it would *not* burn before the oxygen was put in, and *would* burn after it was put in, and as atmospheric air is composed of oxygen and nitrogen, it of course satisfactorily shows, that the oxygen is the *only* supporter of combustion in the air.

CHLORINE.

The word Chlorine is from the Greek language, and signifies *greenish*, in reference to its colour. It is like oxygen, when pure, in a gaseous state, and is the only permanently gaseous substance which has any colour so as to render it visible. In the state of gas, it will support the combustion of some substances, though generally speaking, not so well as common air. Although this is the case, it will inflame some substances, *spontaneously*. Its most useful property, however, is that of removing the *colour* of most substances, and it is the substance now used extensively for bleaching. It has also the same property when it is in what is called a liquid state ; i. e. when the pure air is united with common water.

28. It can be obtained in many ways. The easiest method of obtaining it in a pure state, is by using the oxide of a metal, common table salt, and oil of vitriol.

weeds, after they have been leached for the purpose of obtaining soda. Applied to silver, it has the peculiar property of giving it the colours of the rainbow.

32. Fluorine exists in the fluate of lime, called fluor spar, Derbyshire spar, &c., which is used for ornamental purposes. It is obtained pure, not without great difficulty.

LECTURE VII.

CLASS III.

Acidifiable Substances, and Combustible Substances, not Metallic.

HYDROGEN.

The word Hydrogen is from the Greek language, and signifies to become water, in reference to the fact that when it unites with oxygen, i. e. *burns*, water is the result.

It forms a part of the animal kingdom, the vegetable kingdom, and of water. It is found in less quantities in nature than oxygen. It is usually examined in a gaseous state; in which state it is very light, more than thirteen times lighter than common air. It is the lightest of all substances the weight of which

can be estimated. It is that kind of air with which balloons are filled, in order to cause them to ascend.

33. It can be obtained in this state of air in many ways. The most easy method of obtaining it, is by putting together iron or zinc, oil of vitriol, and water.

I will in the first place refer to a very simple method, by means of which any one can obtain it in small quantities, and be able to illustrate some of its properties without much apparatus.

ILLUSTRATION.

Put into a small vinegar cruet a small quantity (say half a wine glass full) of iron filings, and then add a wine glass of water. Fit a cork to the mouth of the vessel; make a hole through the cork, and pass through it a piece of common pipe stem. Then put into the vessel a small quantity of oil of vitriol, say quarter of a wine glass full. Place the cork with the pipe stem in the mouth. After it boils rapidly, and when we see a stream of vapour passing from the tube, apply a blaze at the end of the tube, and the hydrogen as it passes from it will burn.

Note. Have care and not apply the blaze too soon; for if this is the case, there is danger of an explosion, from the mixture of the hydrogen and atmospheric air in the vessel.*

34. Where it is wanted in large quantities, for experiments, the following is a convenient method of obtaining it.

* In order to be perfectly safe, wrap a strong cloth round the glass vessel. If it should break then, no injury will be the result.

ILLUSTRATION.

Put into a half pint retort half a wine glass of iron filings or turnings, a gill of water, and then turn in half a wine glass of oil of vitriol. Hydrogen gas will be given off, and may be collected in bell glasses and in the gasometer.

Water is composed of oxygen and hydrogen. Here the iron decomposes the water, in consequence of its having a stronger attraction for the oxygen of the water, than that has for the hydrogen. The oxygen unites with the iron, and forms oxide of iron, (common iron rust,) and the hydrogen, being thus thrown off, passes into a gaseous state, its volume is enlarged, and a part of it must pass from the retort; holding the beak of the retort under vessels filled with water, it may be collected as heretofore explained.

35. Hydrogen is very inflammable when in the state of gas.

ILLUSTRATION.

Having filled a large gasometer with it, allow it to pass from it through a small tube. By applying a blaze at the end of the tube, it will be inflamed, and burn with a beautiful, light yellow, lambent flame.

Hydrogen, when thus burning, was formerly called the philosophic candle, and used for the purpose of giving light. It does not answer this purpose very well, however, as there is but little light given out. It is not the substance now used for this purpose, and known by the name of gas light. That is a compound of this and carbon in a gaseous state, as will be explained hereafter.

36. Although hydrogen is itself very inflammable, it will not *support* the combustion of any other substance.

ILLUSTRATION.

Fill a decanter entirely full with it; light a small taper, invert the decanter, and bring the taper, while burning, into it. The taper will immediately be extinguished; but the gas, where it can come in contact with the air at the mouth of the vessel, will be inflamed. Here the gas produces no direct effect upon the taper, but by having the vessel perfectly full, when the taper is brought into it, the taper is so situated that it cannot obtain oxygen to unite with, which is necessary in order to have combustion continued in the air.

37. Hydrogen and oxygen, united by combustion, form water.

ILLUSTRATION.

Take an eight ounce vial, perfectly dry. Prepare a gasometer containing oxygen, having a stop-cock at the top; fix in that a piece of pipe stem six inches long; invert the vial over it, bringing the upper end of the stem near the bottom of the vial; then turn the stop, and let oxygen enough pass into it to fill it twice or three times. By so doing the oxygen will drive out the air, and it will be obtained full, without wetting the vial. Then to illustrate the proposition above stated, hold this vessel over a stream of burning hydrogen. The combustion of the hydrogen will be supported by the oxygen in the vial, or in other words the two will unite and form water; which will be condensed upon the sides of the vessel in minute drops.

38. The same principle can be more easily illustrated by holding over a stream of burning hydrogen a two tubulated globe receiver. Water will be formed as before, by the union of the oxygen of the air with the burning hydrogen. We may see the same fact also illustrated, by holding over the blaze of a common candle, or lamp, any cold glass vessel; the hydrogen which exists in the oil or tallow, as it unites with the oxygen of the air, will form water.

39. When oxygen and hydrogen thus unite and become water, much caloric is given out and becomes free, so that there is a great increase of temperature.

ILLUSTRATION.

This proposition may be illustrated by using the compound blow-pipe.

Fill one of the gasometers with oxygen gas, the other with hydrogen gas; connect one leg of the compound blow-pipe with one gasometer, the other with the other gasometer. First turn the stop connected with the hydrogen; let out a small stream and inflame it. Then let out about half as large a stream of oxygen gas. When these gases unite, in consequence of their becoming a liquid, much heat is given out. Nearly as high a heat can be produced in this way, as has ever been produced in any way. Small pieces of iron, steel, copper, &c. held in this blaze, will be inflamed, and burn brilliantly. Lime, flint, &c. can easily be melted.

40. Hydrogen and oxygen, mixed in certain proportions, will explode when burned.

If instead of allowing the hydrogen to pass through any small aperture, and burn, uniting with the oxygen

gradually, it is first intimately mixed with the oxygen, it will explode with much violence.

ILLUSTRATION.

Mix, in a small vessel, two parts of hydrogen gas with one part of oxygen, or hydrogen and atmospheric air in equal quantities.

Fill a tin pistol with this mixture. The pistol should be about ten inches long, and one inch in diameter; one end left open, the other made tight, with the exception of a small hole within an inch of the bottom. It can be filled by plunging it below the surface of the water, and placing the thumb over the small hole; elevate the bottom above the water, and place the mouth over the tube in the moveable shelf. Turn the mixture under the shelf till it is obtained full.

Then, still holding the mouth below the surface of the water, stop it firmly with a sound cork; elevate the mouth; remove the thumb from the small aperture, and immediately apply a blaze; the mixture will be inflamed, and burn, to appearance instantaneously, with a sharp stunning report. The cork will be thrown from the vessel with much force, so that it will be necessary to hold the pistol in such a position that the cork shall do no injury.

41. Hydrogen gas is very light. That it is so, may be seen by the very simple experiment of inflating common soap bubbles with this gas, instead of common air. They are so much lighter than when filled with air, that they will immediately ascend.

ILLUSTRATION.

Fill a gasometer with hydrogen; fit a flexible tube

LECTURE VIII.

NITROGEN.*

Nitrogen is found in less quantities in nature, than either oxygen or hydrogen. It forms an essential part of the animal kingdom, and of atmospheric air. The difference in the chemical composition, between the animal and vegetable kingdoms, is, that in the animal kingdom there exists nitrogen ; not, with a few exceptions, in the vegetable kingdom.

Its properties are not striking or energetic ; they are all negative, as we might say. It will not support combustion, or continue the life of animals, by breathing. Yet here, it does not produce any direct effect ; the animal dies, and the burning body is extinguished, when in this gas, simply because they are so situated that they cannot obtain oxygen to unite with.

This substance, also, is generally examined in a gaseous state. It is most easily obtained in this state from common air. Nitrogen and oxygen being the only constituents of pure atmospheric air, the *nitrogen* can easily be obtained, by offering to the oxygen a substance for which it has a stronger attraction than it has for the nitrogen.

44. When any substance burns in the air, it unites

* Formerly *Azote*.

with oxygen. So that where combustion is going on, there will always be an increased *proportion* of nitrogen.

ILLUSTRATION.

I will in the first place refer to a very easy method, by means of which any one can obtain it, sufficiently pure for many experiments, without much apparatus. Take a plate ; place in it a piece of thick paper ; place a very short piece of candle, on a teacup inverted in the plate ; light this candle, and invert over it a tumbler. The candle will soon be extinguished. It will continue to burn, however, till most of the oxygen of the air is taken up ; so that when it ceases to burn, what there will be left in the tumbler, will be tolerably pure nitrogen gas.

We may refer to its properties by inverting the whole ; i. e. bringing the tumbler upright. Remove the plate, and leave the paper upon the mouth of the tumbler ; afterwards, remove the paper from a portion of the mouth, and put into it a small candle, or splinter of wood, burning ; they will be extinguished. Atmospheric air is composed of oxygen and nitrogen. The proportions are about 79 parts of nitrogen gas, mixed with 21 of oxygen, in the 100 ; and in this case the oxygen unites with the burning substance, leaving the nitrogen.

45. The more inflammable the substance which we take, the more pure will be the nitrogen. There is one other circumstance, to which it is necessary to have regard ; i. e. the ease of getting rid of the compound formed by the union of the burning body with the oxygen.

Phosphorus, from all these circumstances, answers the purpose very well.

ILLUSTRATION.

Place on the bottom of a wine glass, inverted on the shelf in the cistern, a small piece of phosphorus; inflame it, and immediately place over it a two quart bell glass. Allow it to burn as long as it will. The bell glass will become filled with a deep white vapour, which arises from the union of the oxygen of the air with the phosphorus, while burning; which is *phosphoric acid.* This acid is readily absorbed by water; and as it comes in contact with water, at the bottom of the vessel, it will soon be taken up by it, disappear, and what there will be left in the glass will become perfectly transparent.

The oxygen of the air is here gotton rid of, and the nitrogen left; from the fact that the phosphorus first unites with the oxygen of the air, and forms this white vapour, with which the vessel in the first place was filled. And then this vapour (*phosphoric acid*) is taken up by the water.

46. Nitrogen extinguishes flame, and destroys life if breathed, by excluding oxygen.

ILLUSTRATION.

Fill a small vessel with it, and put into it a taper while burning. It will be extinguished.

Fill a vessel that will hold a quart, or more, which has a large mouth. Put into this a live mouse, or any other small animal. He will immediately die. Here the taper is extinguished, and the animal killed, not by any *direct* effect of the nitrogen, but simply because the vessel being filled with it, *oxygen* is excluded.

47. I have mentioned a number of times, heretofore, the composition of the air; i. e. that it was composed of oxygen and nitrogen, in the proportions, nearly, of four parts of nitrogen gas, to one of oxygen. That this is the case, may be shown by the following experiment.

ILLUSTRATION.

Take four eight ounce vials; fill the first with oxygen, the second with nitrogen, the third with a mixture of nitrogen and oxygen, having four times as much nitrogen as oxygen. Leave the fourth open; it of course will be filled with atmospheric air. Set these near each other. Remove the stoppers from the three first, and place a finger of the left hand upon the mouth of each. Then put a small taper in the *first*—the nitrogen; it will be extinguished. Then remove it immediately into the second—the oxygen; and it will be *relighted*, simply by the heat of the wick. Then place it in the third, i. e. the mixture of the two; and we shall find that it will burn, just as it will in the one left open and filled with atmospheric air. The fourth vial is used, because a candle appears different while burning in a small vessel, from what it does in the open air.

By this experiment, we see, at one view, the nature of the two constituents of the air, both in their separate and in their combined state. We see that it is composed of two substances, differing entirely in their properties. One, the nitrogen, will not support combustion in the least; the taper was immediately extinguished. The other, the oxygen, will continue combustion extremely well; the taper was relighted, sim-

ply by the heat of the wick. We see that a mixture of these two, in the proportions as stated above, forms an artificial air—in all respects, at least so far as combustion is concerned, similar to common air; and if we should collect them in sufficient quantities to ascertain the fact, we should find that this mixture would produce the same effect upon animals when breathed.

48. As we have heretofore illustrated some of the properties of the two constituents of the air, we might with propriety here illustrate some of the properties of this very common substance itself. It will be necessary, however, in this place, to refer to but one of its properties; i. e. that there always exists water, in the state of vapour, in the air.

ILLUSTRATION.

Put into a wine glass a spoonful of common salt; turn on to it a small quantity of oil of vitriol. Muriatic acid will be given off, as was explained under the head of Hydrogen. Though this substance, when pure, is perfectly invisible, as was shown under the head of Hydrogen, and although there is nothing but the muriatic acid given off when these substances are mixed, yet we shall here see a considerable quantity of white vapour passing from the wine glass. It is not the acid which we see, however; *that*, as it passes from the salt, is perfectly invisible: but, as has been stated heretofore, it has a strong attraction for water. As soon, therefore, as it comes in contact with the air, it attracts moisture from it, condenses it, and brings so much of it into so small a space, as to render it visible. The warmer the air is, the more of this water it thus

holds in this state of vapour. So that there is more water in the air, in a dry hot day, than in a damp cold day. But in the former case, it is perfectly dissolved in the air, so as not to be perceptible by our senses. In the latter case, the air becoming cooler, cannot hold so much of it in this state of perfect solution; it is given out in minute drops, and becomes sensible.

ILLUSTRATION II.

49. We may see the same fact illustrated, by filling a glass, in hot weather, with cold water. Water will be condensed on the outside of it. This water, before it was cooled, existed in the air in this state of vapour; but the cold glass cooling a portion of the air with which it comes in contact, it then cannot hold so much water in this state of vapour; it is given out, and being in contact with the glass, adheres to it.

We are dependent on this circumstance, for all the water that falls from the air, in the form of hail, snow, rain, dew, &c. These are all supposed to exist once, in the air, in this state of vapour; are continually passing up by us, and when, in consequence of becoming colder, or from any other circumstance, it cannot contain so much, it is given out, and falls in the form of rain; or if it passes through any medium sufficiently cold to freeze, it then falls in the form of hail or snow.

The water we call dew, falls from the same circumstance; i. e. during the warm season of the twenty-four hours, more water is taken up than the air can contain when colder, and it is therefore, in the evening, given out.

can be obtained in small quantities, by taking the nitric oxide, prepared as directed in the next proposition, and mixing it with oxygen gas. The nitric oxide being composed of two proportions of oxygen, and one of nitrogen, has the property, when exposed to oxygen, of attracting another proportion, so as to become an acid, and is immediately changed from an invisible gas to a deep orange-coloured vapour, and is readily absorbed by water. Both of these acids are generally called, in commerce, *aqua fortis*.

Aqua fortis is often, however, a mixture of both. That kind which is most transparent, and which does not give any red fumes when exposed to the air, contains the most nitric acid; while that which does give off much of these red fumes, is mostly *nitrous* acid.

53. The *nitric oxide* can be obtained, by putting into nitric acid a metal, which will attract a portion of its oxygen.

ILLUSTRATION.

Put into a small retort, a few teaspoonfuls of copper, in small pieces. Then turn on to it half a wine glass of nitric acid, diluted with three times as much water. Apply the heat of a lamp. Collect what passes from the retort, over water. It is the nitric oxide. The reason is this: the copper has a stronger attraction for two proportions of the oxygen of the nitric acid, than the nitrogen has; it therefore attracts, and unites with it, leaving the other two proportions of the oxygen, and the nitrogen, which is the *nitric oxide*. This substance is of but little use.

54. The process for obtaining the *nitrous oxide*, is lengthy and difficult. It is generally obtained from

the nitrate of ammonia, by heating it. We can very seldom procure that substance, and are under the necessity of making it. It may be made thus:

ILLUSTRATION.

Take any quantity of nitric acid, and add to it the same quantity of water. Then put into it carbonate of ammonia till it is saturated; i. e. till the effervescence ceases. The nitric acid unites with the ammonia, and drives off the carbonic acid with which it was previously united; so that we have a nitrate of ammonia, which will, in the first place, be in a liquid state. Expose this liquid to a temperature about as high as at which water will boil, and dry it away to a solid salt. This salt—the nitrate of ammonia—will be in the form of crystals, if the heat in drying it away was not great. But if it was dried away fast, it will be in a fine white powder.

Put a quantity of this salt into a retort, and apply heat gradually; it will melt. Keep it boiling very gradually, and the gas will be given off in great quantities. It should not be heated very high. By continuing this process, the whole of the solid salt will be converted into this gas. It may be collected over water, like the other gases. *Cold* water, however, will absorb about its own volume of it.

55. It will support the combustion of many substances. A candle, put into a vessel filled with it, will continue to burn.

56. It will also continue the life of animals for a short time. It produces, however, a very different effect from common air, when breathed. It can be breathed by filling a large oiled silk or linen bag with

... large stop-cock.

... Apply the mouth to th...
... should through a tube
... ... it should be thu...

... produces very different effe...

... which it *generally* produces. ...
... pain in the head. This ...
... a few seconds. Soon after
... sensation comes on; one which
... simply because there
... which we can compare it
... sensation, which seems
... chest, and extends over the
... rather pleasant.

... the system comes on, the
... affected, and persons under its
... proceed very differently from
... ordinary circumstances.

... a great degree of exhilaration,
... called the *exhilarating gas*.
... its influence is not generally dis-
... perfectly still. Some will speak,
... walk, dance, &c.

... that persons under its influ-
... proceeding in this way. This, in
... correct. They could refrain from
... were disposed to; but that is the
... produces such an effect upon the mind,
... under its influence will draw very dif-

ferent conclusions from existing facts, from what they will before breathing it.

For instance: if a person, before breathing it, should have the thoughts pass through the mind, whether it would be best, every thing considered, to get up and go to singing, dancing, &c. for the amusement of others, he would, probably, under ordinary circumstances, come to the conclusion that it would not, and he would act accordingly. But *after* breathing it, though he can see, hear and think, as before, yet, allowing the same thoughts to come into the mind, his inference might be different. He would probably come to the conclusion that it would be the very best thing he could do, to dance, fence, sing, or something of the kind, and he would immediately put it in execution.

The effect generally lasts but a short time, only about one minute ; though sometimes it lasts much longer. It leaves, as it comes on, almost instantaneously.

Many persons can breathe this without material injury ; though, to most, I am disposed to think it is attended with some danger.

LECTURE X.

SULPHUR.

Sulphur exists in great plenty. It is too common a substance to need any general observations in regard to its properties. It unites with oxygen in three different definite proportions, forming one oxide and two acids.

57. The oxide of sulphur is obtained by melting sulphur in the common air, and exposing it for a long time in this situation, often stirring it. It will attract oxygen from the air, and change, from the pale yellow colour of the pure sulphur, to a reddish brown colour, and become quite tough. This is the oxide of sulphur. It is frequently used for taking impressions.

58. If instead of exposing the sulphur to the air, in this melted state, it is allowed to blaze, it will unite with a larger quantity of oxygen, and an acid will be the result. But as it is not the strongest acid that can be formed by uniting sulphur with oxygen, the name of it ends in the letters *ous*, and it is called sulphurous acid.

ILLUSTRATION.

It may be obtained by taking a plate, in which invert a small cup. Then heat a small piece of tin sufficiently hot to inflame sulphur. Throw on to it

pieces of sulphur. Place it on the cup, in the plate, and immediately invert over it a bell glass or large tumbler. As the sulphur burns, it unites with the oxygen of the air, and forms the acid, which first exists in the state of vapour, but will be easily taken up by the water in the plate.

This acid is not much used as an acid; but it has the property of removing the colour of many substances, and is used extensively for bleaching straw for bonnets.

59. The sulphuric acid (oil of vitriol) may be obtained in many ways. It was formerly obtained by heating what was then called green vitriol (common copperas); and hence called oil of vitriol.

For the purposes of experiment we may obtain it in two ways.

ILLUSTRATION.

Allow it to burn in oxygen gas, as was explained under the head of Oxygen. It will unite with the oxygen, and form the acid, in the gaseous state, as was explained in that place; but will afterwards be taken up by the water at the bottom of the vessel.

ILLUSTRATION II.

It is usually obtained for commercial purposes, by allowing a mixture of sulphur and saltpetre to burn in large chambers lined with lead, having a large quantity of water at the bottom; benches being arranged parallel, and near each other, over the whole floor of the room. The mixture of sulphur and saltpetre is strewed on these, and inflamed.

Here the sulphur obtains a certain quantity of oxygen from the air, another quantity from the saltpetre;

from these two sources, a sufficient quantity to form the strongest acid that can be formed by uniting sulphur with oxygen,—and of course is the *sulphuric* acid.

The acid first exists in the state of vapour ; but coming in contact with water, at the bottom of the room, it will be absorbed by it, and render it sour. When the water has united with a considerable quantity in this way, it is then drawn off, and evaporated till it becomes sufficiently strong for commercial purposes.

60. Sulphur will also unite with hydrogen, and form a compound, which is in a gaseous state. This is called (upon the principle which has already been mentioned for naming the compounds) *sulphuretted hydrogen*.

ILLUSTRATION.

It may be obtained by the following method. Heat iron filings and sulphur in equal quantities together. They may be heated in a crucible, or any thing of the kind. The heat should be continued as long as any blaze will pass from the mixture. By being thus heated, they will unite, and form the artificial sulphuret of iron, which is a dark brown, solid mass. Take a quantity of this, and proceed in the same manner as might be done to obtain hydrogen, by using *pure* iron filings, and the sulphuretted hydrogen will be obtained.

Collect some of it in a vessel, and burn it in the same manner as hydrogen gas. It will burn somewhat similar, only that the blaze will be of a blueish cast.

When it is passing from the retort, allow some of it to pass into cold water, by holding the beak of the

retort in a small vessel containing water. Also allow it to pass through liquid ammonia, in the same way. A portion of it will be taken up by these liquids, and we may thus obtain it in a liquid state.

Both of these liquids are much used in the analysis of metals, mineral waters, &c., having the property of changing the colour of many liquids, in which are dissolved metallic substances. For instance: if added to any liquid which contains any of the salts of lead, it will turn it black; if of iron, a dark brown.

Owing to this property, these liquids answer well as a test for wine, and some other liquids. Sugar of lead is frequently added to wine, and sometimes to beer and cider, for fraudulent purposes, to improve the taste. When any such liquids, in consequence of being long kept, become sour and disagreeable to the taste, the addition of a small quantity of sugar of lead will much improve the taste. But it renders them poisonous. It is not probably often added in sufficient quantities to prove fatal immediately; but if constantly used, it may induce diseases that will ultimately prove fatal, as certainly as if it were taken in larger quantities.

It becomes necessary, therefore, to be able to ascertain where this lead is dissolved, and where not. It *cannot* be done by the taste. It may be very easily done, however, by using a solution of this sulphuretted hydrogen.

ILLUSTRATION.

Add a small quantity of either of the liquids, prepared by allowing the sulphuretted hydrogen to pass through water or liquid ammonia, to any liquid in

which sugar of lead, or any of the salts of lead, are dissolved, and it will turn it to a dark brown, nearly black; and in this way it can be easily ascertained where lead is dissolved in wine.

61. Sulphur, mixed with many substances, will form explosive mixtures.

ILLUSTRATION.

Mix three parts sulphur, two parts saltpetre, one pearlash. They should all be made into fine powder, separately, and thoroughly dried; then mixed intimately.

If a small quantity of this mixture is laid on an iron shovel, or in any similar situation, and gradually heated till the iron becomes nearly red hot, it will explode, with a loud stunning report. The cause of the report is supposed to be the result of the sudden transition of the materials from a solid to an aeriform state; thus producing great and sudden expansion.

LECTURE XI.

PHOSPHORUS.

The word Phosphorus signifies, literally, the bearer of light; in reference to the fact, that it is always luminous in the dark. It is of a reddish yellow colour, of a waxy texture, and highly inflammable.

It is generally obtained from the bones of animals, by a very lengthy process.

Many of its most interesting properties, have reference to its extreme inflammability, as it burns at a lower temperature than most other substances. When pure, it takes fire at 67 degrees Fahrenheit's thermometer; though, as generally obtained at the shops, it does not burn short of a temperature of 120 or 130 degrees. It is usually kept in water, that it may not be inflamed spontaneously.

62. It unites with oxygen, in three definite proportions; forming one oxide, and two acids.

ILLUSTRATION.

The oxide may be obtained, by exposing it to water; its attraction for oxygen being such, that it will decompose the water, and attract the oxygen from it. The white coating on the outside of sticks kept in water, is this oxide. It can also be obtained, by putting a small quantity of phosphorus into a common small vial, and loosely stopping the mouth with a cork. Then warm the vial, and with a piece of wire stir it about while in a half melted state, coating the inside of the vial with it. By the small quantity of oxygen it can obtain from the air in the vial, it will become oxidated.

This oxide is more inflammable than the pure phosphorus. It is the substance used for striking fire, when prepared by the last mentioned method. Taking a small quantity of it upon a common sulphur match, and exposing it to the air, it will usually be inflamed. If it should not be in a few moments, it easily can be, by rubbing it a few seconds on a piece of cork.

63. The *phosphorous* acid is obtained, simply exposing phosphorus to the common air.

ILLUSTRATION.

Place a stick of phosphorus in a small paper funne and put this in the mouth of a small decanter, allow ing a small quantity of water to remain at the bottom The phosphorus will attract oxygen from the air and unite with a sufficient quantity to form an acid. But as it is not the strongest acid that can be formed by uniting with oxygen, the name of it ends in the letters *ous*, and it is called the phosphorous acid. The acid, thus obtained, will appear in a stream of white vapour, descending from the funnel to the bottom of the vessel, will unite with the water, and render that sour.

When phosphorus thus attracts oxygen, (as it always does when exposed to the air,) it undergoes a slow combustion; sufficient, however, to give out a small quantity of light and heat; and it is owing to this fact, that it is always luminous in the dark.

64. To obtain the *phosphoric* acid, we have only to allow it to burn, with a *blaze*, either in the common air or pure oxygen gas. So great is its attraction for oxygen, that it will unite with its highest proportion; i. e. form the strongest acid that can be formed, by uniting with oxygen, simply by allowing it to burn in the air. The same acid is formed, when it burns in pure oxygen gas. The only difference is, that in the latter case it will burn with much more brilliancy.

ILLUSTRATION.

Place in a dry plate a small piece of phosphorus. Inflame it, and immediately invert over it a bell

glass, or large tumbler, perfectly dry. As the phosphorus burns, the acid will be formed; first existing in the form of a deep white vapour, but as it cools it will fall to the plate, in a white, floculent powder, imitating a snow storm on a very small scale.

ILLUSTRATION II.

Fill a quart decanter with oxygen gas, leaving a small quantity of water at the bottom. Fit a piece of tin to a cork, as was explained under the head of *Oxygen*, and allow a small piece of phosphorus to burn in the gas. It will burn with intense brilliancy, giving out a very great quantity of heat and light, and probably break the vessel.

The same acid will be formed as before, but will soon be taken up by the water in the vessel, and render it sour.

This is one of the most brilliant experiments in chemistry. The light thus given out is much more intense than that of the meridian sun.

65. As has already been stated, phosphorus is extremely inflammable; that it is so, may be seen by allowing it to burn in cold water,—a situation in which we do not often see combustion go on.

ILLUSTRATION.

Take a small tumbler, one eighth part filled with cold water; cut in small pieces a small quantity of phosphorus, and put in the water. It will sink. Scatter upon it a little *chlorate of potash*. Fit a piece of pipe stem in a glass tube, eight or ten inches long, by winding flax around it and screwing it firmly into the tube, holding the end of the stem at the bottom of the tumbler. Turn into the tube a quantity of *strong*

oil of vitriol. The phosphorus will be inflamed, and burn with a bright, irregular flame, even in defiance of the presence of the cold water.

The chlorate of potash contains a large quantity of two of the best supporters of combustion, (oxygen and chlorine,) which the *acid* throws off, by decomposing the salt. These, coming directly in contact with the phosphorus, inflame it, even under these disadvantageous circumstances.

66. Phosphorus, when exposed to the air, is always luminous. It has, also, the property of imparting the same luminous appearance to many liquids, in which it can be dissolved; such as ether, some kinds of spirit, and oil.

ILLUSTRATION.

With a piece of phosphorus, write on a smooth board, or paper; and this writing can be read in the dark, in consequence of the small quantity of phosphorus thus rubbed off being luminous: and that it unites with oxygen in this case, in sufficient quantities to form an acid, when thus exposed to the air, may be seen by writing on *blue* paper. Wherever it touches the paper, the colour, after the luminous appearance has ceased, will be changed to a red; indicating the presence of an acid.

ILLUSTRATION II.

That it renders oil luminous, when dissolved in it, may be shown thus:

Into four ounces of sweet oil, having it in a vial, put a stick of phosphorus half an inch long, of the ordinary size. Gradually heat this oil, and when about as hot as boiling water, i. e. when the phos-

phorus is thoroughly melted, shake them intimately together.

Allow it to cool. This oil, when exposed to the air, will be luminous. If put upon the hands, or hair, it will have the appearance of a faint white blaze; though in this case there is but very little heat given out.

LECTURE XII.

CARBON.

Carbon exists pure in the diamond. Next to this, the different kinds of coal contain it in the greatest plenty.

The only difference, chemically speaking, between the diamond which is so extremely valuable, and charcoal which is so plenty, is, that the one is crystallized, the other is not.

If carbon could be easily crystallized by art, as most other substances can be that are ever crystallized, the diamond would at once lose most of its nominal value. For the value of this, as well as most of the other precious stones, metals, &c. which bear an extremely high price, depends more upon their scarcity than any other one circumstance.

For instance, if the diamond, which now bears the highest price of any other substance whatever, was as *plenty* as glass, which it almost exactly resembles and to the unpracticed eye cannot be distinguished from it, it could not bear so high a price as *that* very common substance now does. The simple reason is, it cannot be wrought into articles which shall subserve our convenience—which shall answer so good a purpose in the arts, as that substance.

With the exception of its being extremely hard, and from this circumstance used for cutting glass, I know not that it is used much in the arts.

It is possible that carbon may be hereafter crystallized artificially, though it cannot be said that it is very probable.

When it was found that it could be melted, it was at once thought that it could be crystallized; because most substances that are not crystallized by being dissolved in some liquid, are crystallized by being melted; i. e. dissolved in caloric. Most of the metallic substances can thus be crystallized. But as yet, no method has been adopted by means of which it could be allowed to cool under such circumstances as to be obtained in a crystalline form.

The cost of the diamond will of course exclude it from experiments in this place. We may, therefore, refer to some of the properties of the substance in which carbon exists pure next to the diamond; i. e. common charcoal. This substance possesses many useful properties, aside from being used as fuel.

67. The first to which we may refer, is this: that charcoal has the property of absorbing a certain

quantity of every kind of air, or gas, to which it is exposed, when *cold*, and of giving it off again unchanged when heated. On this very simple property of charcoal, depend most of its uses, except that of combustion; and it has many. It is used as a dentifrice, to preserve the teeth; to preserve water, when carried long voyages at sea; to preserve fresh meat; to remove bad odour from many substances; as manure, spread on the ground, to cause vegetables to grow better; and in all these cases answers the purpose very well.

68. I might in the first place refer to a method of preparing it for a dentifrice. It is thought by many, that it is one of the best substances that can be used for this purpose; the grit of it being sufficient to answer well the purpose of scouring the teeth; and owing to its other properties, it tends to prevent their decay.

It is best prepared for this purpose, thus: Take the charcoal of hard wood and make it into a fine powder. Place it in any convenient situation where it can be heated quite hot; on a shovel, or in a small iron vessel, or any thing of the kind. While hot, turn it immediately into clean cold water. It will absorb water and sink in it.* When used, the whole should be shaken together; the powder used to scour the teeth, the water to rinse the mouth. Aside from the good effects which it produces upon the *teeth*, it has, at least, one other very agreeable property; i. e. it serves, as well as any other substance that can be used, to render the breath sweet.

* It should be kept in a glass vessel, corked tight.

69. Carbon will unite with oxygen and form carbonic acid.

If a piece of the diamond, which is pure carbon, is caused to burn in a vessel containing oxygen, the result will be carbonic acid. The same acid is also formed, when *charcoal* burns in the same situation.

ILLUSTRATION.

Fill a quart decanter with oxygen gas. Fit a strip of tin to a cork which fits the mouth of the decanter, as described under the head of Oxygen. Place a small piece of charcoal on the end of the tin ; inflame it, and put it into the decanter. It will burn, throwing off bright sparks for a short time. When it ceases, we shall find a substance in the decanter, possessing very different properties from the oxygen gas ; i. e. carbonic acid. By putting a taper into it, it will be extinguished. And it is so much heavier than common air, that it can be turned from the decanter on to a candle so as to extinguish it ; or into a tumbler, and it will remain there some time, as may be shown by putting a candle into the tumbler, where it will also be extinguished.

70. This acid, when wanted in large quantities, can more easily be obtained from its different states of combination with other substances, called carbonates ; such as chalk and marble, which are carbonate of lime ; or from pearlash, or sal æratis, which are the carbonates of potash.

ILLUSTRATION.

Put into a retort a wine glass full of common pearlash, or, what is better, sal æratis. Then turn on to it

a small quantity of oil of vitriol, diluted with *twenty* times as much water.

Carbonic acid will be given off, in great plenty; and when it ceases, add a little more of the acid. It can be collected, like other gases, over water. Fill decanters with it. That it is much heavier than common air, and that it will not support combustion, or the life of animals by breathing, may be shown, thus:

ILLUSTRATION.

Put a burning taper into a vessel filled with it; it will be extinguished. Put a living animal in a vessel containing it; life will be destroyed.

ILLUSTRATION II.

Having filled a decanter with it, take a tumbler and put into it a burning taper. It will burn as out of it. Then invert the mouth of the decanter over the tumbler, and remove the stopper. After holding it in that situation a short time, though there will be nothing perceived passing from it, yet we shall find, that on again applying the taper to the tumbler, as before, it will be extinguished; showing that it has descended from the decanter into the tumbler, and of course must be heavier.

There are but few chemical compounds, with which we come in contact more often, in the common concerns of life, than this substance; sometimes under such circumstances, that it is necessary to get rid of it, and sometimes where it is necessary to retain it.

This is the substance which is frequently found in deep *wells*, caverns, cellars, &c. and which destroys life on going into such places. It is also the same which is given off when common charcoal burns in the

air ; and persons frequently lose their lives by being exposed to the vapour which arises from charcoal burning in a tight room.

We can easily keep clear of its bad effect, if we are acquainted with its properties ; bearing in mind that it is much heavier than common air, and of course that it will occupy the lowest situations. There is no danger of burning charcoal in a room, if there is a free passage for the escape of this acid from the *bottom* of the room ; but it will not answer the purpose to have an aperture in the upper or middle part of the room, as raising a window, &c. For it is so much heavier than the air, that the lower part of the room may be filled with it tolerably pure, up even with the aperture.

When this acid is found in low situations, as in a well, cavern, cellar, &c., it is sometimes very necessary to get rid of it. This may easily be done, by bringing in contact with it a solution of any of the alkalies, or lime water.

We can ascertain *where* it is, by noticing the effect produced upon a common candle ; as it will not support combustion. Whenever we find, therefore, that a candle will not burn in any *low* situation, such as a well, &c., it is almost certain that this gas is present ; for it is the only one which is found in any considerable quantities in the air, which is heavier than that is.

When found in such situations, turn down a solution of *potash* or common lime water, and they will take it up.

These liquids take it up, from this circumstance :

It unites with the potash, or lime, and becomes solid, forming a carbonate, and thus occupies a much less space. Its properties are also changed.

71. That these liquids will thus take it up, may be shown by taking some of it in a tumbler. By putting a candle into it, we shall find it will be extinguished. Then turn into it a small quantity of lime water. Again apply the candle, and it will burn; and in this case we shall find, suspended in the lime water, a fine white powder, which is common chalk; i. e. *carbonate of lime.*

72. It is always found in small quantities in the atmosphere; not that it forms a part of the air, but being thrown off into the air from different circumstances in small quantities, it floats in it.

It may be illustrated in this way: Take an eight ounce vial perfectly clean, put into it a small quantity of lime water, shake it about thoroughly; it will become whitish. We have heretofore seen that carbonic acid has the property of producing this change on lime water when it comes in contact with it, by uniting with the lime and forming chalk: and here there is a sufficient quantity of this carbonic acid in the atmospheric air, with which the vessel is filled, to unite with a portion of the lime which is dissolved in the water, to form this white powder (chalk) suspended in the water, and to produce this appearance.

73. It is continually given out by animals, at every respiration.

ILLUSTRATION.

Take a small quantity of lime water in a wine glass, and allow a person to breathe through it by means of

a glass tube, or pipe stem; it will soon turn white as before, and from the same circumstance; i. e. carbonic acid being given out from the lungs, unites with the lime, and becomes chalk as before. The carbonic acid is formed in breathing, it is supposed, in consequence of the oxygen of the air absorbing carbon from the circulating blood in the lungs.

There is one fact here worthy of notice. We have seen, that when any substance burns in the air, oxygen is consumed; if the substance which burns contains carbon, (i. e. charcoal,) then this acid is formed; also, when animals breathe, the same acid is formed. We might be led to suppose that after a while all of the oxygen should be taken up, and leave us only carbonic acid and nitrogen, neither of which will support combustion, or continue the life of animals by breathing.

This would probably be the case, were it not for the vegetable kingdom. As we saw under the head of Oxygen, growing vegetables give out oxygen gas. They are supposed to give it out, from this circumstance: During the night, they are supposed to absorb carbonic acid from the air; and in the day time, when exposed to light, during the process of vegetation, to decompose it, take away the carbon, which goes to form a part of the vegetable (that part which can afterwards be obtained from them in the form of charcoal), while the oxygen of the carbonic acid is given off into the air—again to support the process of combustion—again to answer the purpose of respiration by animals.

74. Carbon will unite with hydrogen, and the com-

pound is in a gaseous state; on the principle which has been mentioned for naming these compounds, it is called the *carburetted* hydrogen.

It is that kind of gas which is used for giving light, and known simply by the name of gas light.

It can be obtained from a great variety of substances, such as oil, wax, tallow, tar, &c.; or compounds which contain any of these substances. It is usually obtained, either from a kind of mineral coal, (that kind which will burn freely with a blaze,) or from damaged lamp oil.

ILLUSTRATION.

Take a quantity of what is called *orral coal;* pulverize it. Fill a gun barrel, fitted as was explained under the head of Oxygen, one third full of it.* Having connected the lead tube with it, place that portion of the barrel, in which the coal is placed, in such a situation that it can be heated gradually,† and bring the end of the lead tube under the bottom of the gasometer. When the barrel becomes heated, the gas will be given off in great quantities. It may be collected over water. When it does not pass off fast enough, bring the barrel forward, so as to expose a larger quantity of the coal to the heat.

After having collected a sufficient quantity, fix a small tube to the stop-cock, at the top of the gasometer (a pipe stem will do); turn the stop, and apply a

* It must not be the one used for collecting oxygen; that must be used for no other purpose.

† The same furnace may be used that was explained under the head of Oxygen.

blaze at the end of the tube. It will be inflamed, and burn beautifully, giving out much light.

This gas is obtained upon the same principle, where it is used for the purpose of giving light.

BORON.

This substance exists in but small quantities. It may be obtained from boracic acid, which forms a part of common borax. It is of a dark brown colour; has but lately been discovered, and is not applied to any useful purposes.

LECTURE XIII.

CLASS IV.

METALS.

The metals form a numerous and important class of natural substances. With the exception of the bases of the alkalies, they have all a specific gravity of more than five; i. e. they are more than five times as heavy as water. They all reflect light brilliantly, which is called their metallic lustre. They are all conductors of light and electricity. They all have the property of uniting with oxygen and the oxides;

all have the property of uniting with all the acids, and forming *salts*. They all have the property of uniting with sulphur, and forming sulphurets. Most of them have the property of uniting with phosphorus and carbon, and forming phosphurets and carburets.

I will, in the first place, refer by experiment to a few properties which all the metals possess in common.

PROPOSITION.

75. All the metals must be in the state of oxides, before they can unite with acids and form salts.

ILLUSTRATION.

Put mercury into muriatic acid. No effect will be produced: because the metal is not oxidated, and the muriatic acid cannot be decomposed by it and furnish oxygen, and mercury cannot decompose water.

ILLUSTRATION II.

76. Put the same metal into nitric acid. There *will* be an action, and the result will be the nitrate of mercury. This might, at first, be considered against the proposition which we have taken; but is not so in reality, for the effect is easily explained.

Nitric acid contains a large quantity of oxygen, and is easily decomposed, and gives it off to other substances. Here, therefore, a portion of the acid is decomposed; the oxygen given off unites with the mercury and forms an *oxide;* then other portions of the acid, which has not been decomposed, unite with this oxide and form the salt.

77. 3d. Put iron into muriatic diluted with water, and there will also be an action, and the result will

be a salt ; i. e. muriate of iron. As we have already mentioned that muriatic acid could not be decomposed and furnish oxygen to other substances, as the nitric acid does, this also might be considered against the above proposition ; but it can also be as easily explained. For though neither the iron nor any other metal can decompose the muriatic acid, and thus obtain oxygen, yet the *water* is easily decomposed by the *iron*.

Here, therefore, the iron becomes oxidated, by decomposing the water, and then the acid unites with this oxide and forms the salt.

The metals being very numerous, are usually, for the assistance of the learner, divided into classes. The only arrangement which will be necessary in this short sketch, perhaps, will be to divide them into two classes. 1st. Those which are obtained from the alkalies ; and 2d. Those obtained in any other way. The first of these are frequently called metalloids. They have but lately been discovered. Their oxides have been long known, under the name of alkalies, alkaline earths, &c. such as potash, soda, lime, and were formerly supposed to be simple or elementary substances : but lately they have been decomposed, and found to be simply oxides of metals ; i. e. potash is not a simple substance, but is composed of a metallic substance somewhat in appearance like mercury united with oxygen—is simply the oxide of a metal ; and so on with the others. These metals receive names from the substances from which they are obtained, with a slight difference in the termination ; i. e. the one obtained from potash, is called *potassium*

—that from soda, *sodium*—that from lime, *calcium*, from calx, the *Latin* word for lime, &c.

The metals can be separated from the oxygen, by exposing the alkalies to a high and long continued heat under certain circumstances. Such experiments require much time and expense, and however interesting they may be to the proficient in this science, they do not illustrate principles which are of any great practical utility.

I will, therefore, refer to some of the properties of these substances in the state in which they exist in nature ; i. e. in the state of potash, soda, &c.

Many of these experiments will have reference to the union of the substances in this class with the acids.

SECTION I.

POTASH.

78. This substance receives its name from the vessels in which it was formerly made. When pure, it itsometimes called potential cautery, and was formerly used by surgeons for opening abscesses, &c. though it does not answer the purpose very well.

79. It may be obtained pure, by mixing the common pearlash of the shops (which is a carbonate of potash) with lime.

ILLUSTRATION.

Dissolve any quantity of pearlash in water ; then add newly slaked lime. The lime will unite with carbonic acid and form carbonate of lime, and the pure potash will remain dissolved in the water. Take

ILLUSTRATION.

Take any quantity of liquid soap, heat it, and put into it a small quantity of common salt; stir it thoroughly, afterwards drain off the liquid. What there is left solid will be tolerably good hard soap.

LECTURE XIV.

Continuation of the Same.

AMMONIA.

This is frequently called *volatile* alkali, in distinction from potash and soda, which are called *fixed* alkalies. It is also frequently called hartshorn, from the fact that it was first obtained by distillation from the horns of the hart or deer.

It is not, like potash and soda, the oxide of a metal, but is composed of hydrogen and nitrogen. It is noticed in this place, because it has many properties in common with the other alkalies. Like them it unites with the acids and oils. When pure, it is in a gaseous state, and easily passes into that state from many *solid* substances in which it exists; hence, called volatile.

86. It is easily obtained from the muriate of ammonia (sal. ammoniac), by mixing it with lime.

ILLUSTRATION.

Coarsely pulverize a small quantity of muriate of ammonia; mix with it twice as much newly slaked lime. Put them into a small retort, and apply heat. Ammoniacal gas will be given off in great quantities. When wanted *pure*, it can be collected only over mercury, as it is rapidly absorbed by water.

87. Allow some of the gas, when thus passing from the retort, to pass through common water; it will be absorbed, and form what is called liquid ammonia, or *hartshorn;* or by allowing it to pass through *spirits* of any kind, it will form what is called spirits of hartshorn.

88. Amusing experiments may be performed by allowing this gas, while it is passing from the retort, to pass into a vessel perfectly dry, and filled with, or into which is passing, a stream of carbonic or muriatic acid. The two aeriform bodies will immediately become a dry *solid* powder—muriate or carbonate of ammonia.

89. The carbonate of ammonia (salts of hartshorn) is generally formed by heating the muriate of ammonia and common chalk together; the carbonic acid of the chalk uniting with the ammonia, and the muriatic acid of muriate of ammonia with the lime; affording an instance of what is called double elective affinity.

90. Ammonia will unite with nitric acid and form the nitrate of ammonia, which is used for obtaining the *nitrous oxide* (exhilarating gas); the particular method of obtaining which, was given under that head.

[illegible] exists in
[illegible] marble.
[illegible] lime is
[illegible] and
[illegible]
[illegible]

[illegible]

[illegible]

[illegible] change of

[illegible] are [illegible]
[illegible] taste. When
[illegible] tasteless.
[illegible] common *plaster of*

[illegible] should be washed
[illegible] be tasteless.

BARYTES AND STRONTIAN.

These two substances exist in but small quantities. They have some properties in common with lime, which in appearance they somewhat resemble. They are not applied to many practical purposes.

MAGNESIA.

This substance much resembles the others in this class; only it is much less powerful. Common magnesia of the shops is the carbonate; that substance heated, and the carbonic acid driven off, gives us what is called calcined magnesia, which is magnesia in a tolerably pure state.

92. It will unite with sulphuric acid, and then forms what is generally called Epsom salts; i. e. sulphate of magnesia.

That substance is found in great plenty, in many places, in a natural state. It received the name of Epsom, from the circumstance of its being found in great plenty in a place of that name in England.

It is also found in great quantities in the town of Hoosack, on the North River, in the State of New York.

SILEX AND ALUMINE.

93. These earths, from analogy, are generally placed in this class, and supposed to be oxides of metals, though there is some doubt upon the subject. Of

alumine we have a specimen in the different kinds of clay. It is used extensively for making the different kinds of earthen ware ; and when perfectly pure, affords us the most beautiful kinds of porcelain.

94. Of silex, we have specimens in the different kinds of sand, rock crystal, &c. ; and it is used, being heated with some of the alkalies, to make glass.

LECTURE XV.

SECTION II.

Metals not obtained from the Alkalies.

IRON.

95. Iron is found in great abundance. It is the most useful of all the metals. In the arts it is divided into three kinds,—cast iron, wrought iron, and steel.

96. Cast iron is an impure carburet of iron. Wrought iron is manufactured by heating cast iron, and, while hot, hammering it. By the heat, much of the carbon is burned out ; and by hammering, it is made more solid—so that wrought iron may be said to be tolerably pure iron.

97. Steel is manufactured from wrought iron by

heating it in contact with charcoal, under such circumstances that the coal cannot burn, as in a close oven. The iron attracts carbon, and again becomes a carburet.

98. The oxide of iron forms the colouring matter of most vegetable and mineral substances. The colour of most flowers, as well as the blood of animals, contains it. The oxide, when united with sulphuric acid, forms common copperas.

ILLUSTRATION.

Put into sulphuric acid, diluted with water, iron in small pieces. It will become oxidated by attracting oxygen from the water, and then the acid will unite with this oxide and form sulphate of iron—common copperas.

MANGANESE.

Manganese is generally found in the state of an oxide, having so strong attraction for oxygen that it will attract it from air or water. When pure, it is of a dark grey colour, much resembling zinc. Oxygen can be obtained from it, as was explained under the head of Oxygen.

TIN.

This substance is not found in very great plenty. Owing to the fact that it is not oxidated when it is exposed to air and moisture at ordinary temperatures, it is much used in the arts.

99. Though it is not oxidated at common temperatures, it can easily be oxidated by being heated.

ILLUSTRATION.

Heat a quantity of tin foil or common block tin, and stir it while melted and exposed to the air. It will attract oxygen and become a dry white powder, which is the oxide of tin.

100. This oxide is used for burnishing metals. It is also used, mixed with oil, for sharpening edge tools —such as surgical instruments, razors, &c.—under the name of metallic paste.

101. Melted with glass, it forms the enamel for the faces of clocks and watches.

102. Tin can be dissolved in mercury, and this amalgam is the substance used on the backs of mirrors.

ZINC.

Zinc, united with copper, forms brass. With lead, it forms pewter. It also forms a part of the different kinds of bell metal. Exposed to a strong heat, it will be inflamed.

103. The oxide, thus formed, is so light that it will float in the air.

ILLUSTRATION.

Put a small quantity of common zinc into a crucible, and expose it to a high heat ; it will take fire.

104. The oxide will unite with sulphuric acid, and form sulphate of zinc, which is generally called white vitriol.

ILLUSTRATION.

Into a small quantity of sulphuric acid, diluted with water, put zinc in small pieces. It will be dissolved,

and the sulphate of zinc formed. The zinc becomes oxidated, by decomposing the water, in the same manner as iron does, and the oxide unites with the acid to form the substance in question.

ARSENIC.

Arsenic, when pure, has a strong metallic lustre, is of a light grey colour, and very brittle. Like some of the other metals, it unites with oxygen in sufficient quantities to become an acid.

The white arsenic of the shops (ratsbane, as it is generally called) is the arsenious acid. It is extremely poisonous.

105. Thrown upon burning charcoal, it has the property of giving off a strong odour of garlic,—a property possessed by no other metal. This affords us a very good test for the presence of arsenic.

COPPER.

Copper is of a reddish colour. It undergoes but little change in a perfectly dry atmosphere, but is effected in a short time by exposure to air and moisture, being converted into a green carbonate, which is poisonous. United with sulphuric acid, it forms sulphate of copper, generally called blue vitriol. With acetic acid (common vinegar), it forms acetate of copper. Common *verdigris* is this substance, in a very impure state.

ANTIMONY.

Antimony generally occurs in the state of a *sulphuret*. When pure, its colour is white, with a tinge of blue. United with tartaric acid, it forms the tartrate of antimony, which is generally called *tartar emetic*. This substance, dissolved in wine, forms what is called antimonial wine.

BISMUTH.

Bismuth is of a reddish yellow colour, a little harder than lead, and very brittle.

106. It unites easily with nitric acid, and its solution in this substance is the basis of a sympathetic ink.

ILLUSTRATION.

Dissolve bismuth in nitric acid, diluted with an equal quantity of water. Write on white paper with this solution. When dry, it will be invisible. Afterwards wet the paper, and it will make the writing visible.

107. The oxide of bismuth used in medicine, called by some the sub-nitrate, can be obtained from the liquid nitrate by adding any of the alkalies.

ILLUSTRATION.

Take any quantity of nitrate of bismuth prepared as above directed, and add common pearlash. There will a white powder fall to the bottom, which is the oxide of bismuth. It should be washed in water.

LECTURE XVI.

Continuation of the Metals.

GOLD.

Gold is a yellow metal, very soft, tough and malleable. It is soluble in nitro-muriatic acid and aqueous chlorine, and these are the only liquids that will dissolve it.

108. When dissolved in either of these liquids, it can be used for gilding steel, ivory, &c.

ILLUSTRATION.

To any quantity of its solution in nitro-muriatic acid, add twice as much ether, and shake them together thoroughly. After letting them stand a few minutes, turn off about one third of the liquid. Dip a piece of ivory or polished steel in this liquid, then plunge it into water. Afterwards burnish it, and it will be found beautifully gilt.

SILVER.

Silver is the whitest of all metals. Like gold, it is not easily oxidated.

109. It can be dissolved in many of the acids. Its

solution in nitric acid is of much utility. It is called *lunar caustic*. It is used for making the indelible ink.

ILLUSTRATION.

Dissolve a stick of the lunar caustic, of the ordinary size, one inch long, in an ounce of pure water, and it will be very good indelible ink.

ILLUSTRATION II.

The nitrate of silver, i. e. lunar caustic, may be directly formed, and it will answer the same purpose.

Take a drachm of nitric acid, diluted with an equal quantity of water. Put in *pure* silver as long as it will be dissolved. The liquid thus prepared is the ink.

110. If we cannot obtain pure silver, we can use common silver *coin*, which is a compound of silver and copper, one part copper to eleven of silver.

First dissolve the silver coin in nitric acid, as heretofore directed. Then put into the liquid, thus prepared, a piece of clean, bright copper. The copper will unite with the acid, and form nitrate of copper, and all the pure silver which there was in the coin will be precipitated in a fine powder.

Take this powder, again dissolve it in the acid as was described in the first place, and the liquid will be the ink.

111. The ink may be coloured by putting into it a few drops of common writing ink; and it will be more convenient to use, if a small quantity of gum arabic is dissolved in it.

This ink is called the indelible ink, because, used upon white cloth, it cannot be washed out; and hence it is used for marking.

112. The preparation used upon the cloth where we wish to write, is a solution of *soda.*

ILLUSTRATION.

Dissolve a small quantity of common soda in water, say a tea-spoonful to half a wine glass, and add a small piece of gum arabic. Wet the place where we wish to write, with this liquid, and, when nearly dry, iron it smooth. Write with the ink prepared in any of the ways mentioned, using a clean pen. Lay it in the sun to dry, and after a few hours it will become black, and cannot be washed out.

MERCURY.

Mercury is generally found in the state of a sulphuret, from which the mercury is separated by distillation with lime or iron filings.

It is of a brilliant white colour, much like silver, and hence the terms *hydrargyrum*, *argentum vivum*, *quicksilver*, &c. by which sometimes it is called.

It is always liquid at common temperatures, but becomes solid if reduced to a temperature of 40 degrees Fahrenheit's thermometer.

113. Mercury unites with oxygen, with acids, and chlorine, and forms compounds, which are much used.

Red precipitate is an oxide of mercury.

114. Chlorine unites with it in two proportions, forming a protochloride and a perchloride. These compounds are usually called *calomel*, and *corrosive sublimate*; sometimes, though improperly, *submuriate* and *oxymuriate* of mercury. The subnitrate and sulphuret is also sometimes used as a medicine.

PLATINUM.

This metal is found in small grains in South America, frequently mixed with the ore of silver. The word platinum means "little silver." It is the heaviest of any of the metals. It is not easily oxidated, and will bear a very high heat without melting, and is hence used for crucibles and the lenses of large telescopes, which are exposed to a great heat.

LEAD.

This metal is usually obtained pure from the sulphuret. It melts at a low temperature, and is easily converted into an oxide. Air alone produces but little effect upon it, but it is slowly corroded when exposed to air and water.

115. *Litharge* and *red lead* are both oxides of lead, but the red lead contains more oxygen than the other.

116. Acetic acid unites with lead and forms acetate of lead, which is generally called *sugar of lead*, and is used as a medicine, &c.

117. White lead, used as a paint, is the carbonate of lead.

118. The remaining metals, Cobalt, Nickel, Tungsten, Tellurium, Molibdenum, Uranium, Titanium, Chromium, Columbium, Palladium, Rhodium, Iridium, Osmium, and Cerium, are used but little in the arts. They exist in but small quantities, and have most of them been lately discovered. It will not be necessary to refer to any of their properties in this short sketch.

LECTURE XVII.

ORGANIC CHEMISTRY.

Organic Chemistry comprehends the history of animal and vegetable compounds. These bodies, viewed collectively, form a remarkable contrast to those of the mineral kingdom.

Mineral substances are generally characterized by containing some principle peculiar to each ; thus the presence of phosphorus in the phosphoric acid, and of sulphur in the sulphuric acid, establishes a wide difference between these two substances.

The products of animal and vegetable life, on the contrary, consist of the same elementary principles, the number of which is very limited. Organized bodies are nearly all composed of oxygen, hydrogen, carbon, and nitrogen, united in different proportions. Small portions of phosphorus, sulphur, iron, silex, potash, lime, &c. are, however, sometimes found in them, but their quantity is exceedingly minute, compared with the principles above mentioned.

Another circumstance which is characteristic of organic products, is the impracticability of forming them artificially by direct union of their elements. Thus, no chemist has hitherto succeeded in uniting

carbon, hydrogen, and oxygen, so as to form any vegetable compound, such as starch, sugar, &c.; which nevertheless are composed of these elementary substances.

Organic substances, owing to the energetic affinities with which their elements are endowed, are very prone to spontaneous decomposition. They can be all decomposed by submitting them to a high heat.

Organic substances, we might say, therefore, are characterized by the following circumstances. 1. By being composed of similar elements. 2. By the impracticability of forming them artificially, by direct union of their principles. 3. By the facility with which they undergo spontaneous decomposition. 4. By being decomposed at a high heat.

Of Vegetable Substances.

The ultimate principles of vegetable substances are few in number; but these, by being combined in various proportions, give rise to a series of compounds materially differing from each other, and which may be called their *proximate* component parts.

Carbon, hydrogen, and oxygen, are the principal *ultimate* components of vegetables; some, however, contain nitrogen. By ultimate principles, is meant the last term of the analysis, or what has been explained as a simple substance; i. e. a substance that has never been decomposed or resolved into others more simple, or reproduced by artificial means.

The ultimate analysis of all vegetable and animal substances, is one of the most difficult processes in

chemistry. As a description of this process is very lengthy, and difficult to understand without *much* study, it may here be omitted, and we may proceed to take some notice of what is called the *proximate* principles of vegetables. These are more numerous than the ultimate principles.

The most important of them are Gum, Sugar, Starch, Gluten, Extractive Matter, Tannin, Colouring Matter, Wax, Oil, Camphor, Resins, Narcotic Principles, Bitumen, and the Vegetable Acids.

GUM.

Gum is contained in considerable quantities in the sap of many vegetables, and sometimes appears as a spontaneous exudation. Gum arabic may be taken as a specimen. All the gums are soluble in water, and insoluble in alcohol. None of them can be crystallized.

SUGAR.

Sugar may be extracted from the juice of many vegetables, and is contained in all those having a sweet taste. Common sugar is usually obtained from the juice of the sugar cane, though it can be obtained from many other substances ; such as the sugar maple, beets, carrots, parsnips, the stalks of Indian corn, &c. Its taste is a pure sweet. It is more soluble in water than in alcohol. It is easily crystallized.

STARCH.

Starch is obtained from many substances. It is found in the esculent grains, horse chesnuts, potatoes, and many other substances.

It is a white powder, insoluble in cold, but easily dissolved in warm water. Sugar and starch differ but little in composition, and the change of starch into sugar is always observed during the germination of seeds.

Arrow-root, sago, tapioca, cassiva, and salop, are only different preparations of starch.

GLUTEN.

This substance is an essential ingredient in wheat flour, and gives considerable tenacity to its paste. It is the large quantity of gluten in wheat flour, compared to other grain, that renders it peculiarly fit for making bread; for the carbonic acid, extricated during the fermentation of the paste, is retained in consequence of its adhesiveness, and thus forms a spongy and light loaf.

EXTRACTIVE MATTER.

By the term extract, or extractive principle, is meant a substance contained in most vegetables, and which forms the principal ingredient in the pharmaceutical preparations, called *extracts*. It is soluble in water and the different kinds of spirit.

TAN, OR TANNIN.

This astringent principle is contained in large quantities in oak bark, gall nuts, catacu, grape seeds, and the wood of the common chesnut; and in smaller quantities in many other substances.

The most distinctive character of tannin, is that of affording an insoluble precipitate, when added to a solution of any animal jelly. Upon this property the art of tanning depends, for the skins of all animals contain gelatin, with which the tannin unites and forms an insoluble compound,—*leather*.

A substance possessing similar properties to tannin, can be prepared, *artificially*, by the action of nitric acid on charcoal, or any carbonaceous substance.

COLOURING MATTER.

The colouring matter of vegetables is very seldom found uncombined with other matter. It resides in many vegetable principles. Its extraction and transfer to different substances, constitute the art of *dyeing*.

Sometimes the colouring matter has an attraction for the stuff which is to be coloured, and then no other substance is needed. When this is not the case, a third substance has to be used which has an attraction for both. Such substances are called *mordants*. For instance, wool has but little attraction for any red colouring matter, but common *allum* has an attraction for both the wool and the colouring matter; therefore, by the use of this the red colour is produced. The allum here is the mordant.

LECTURE XVIII.

ANIMAL CHEMISTRY.

The animal creation is the most complicated order of compound beings: still, however, animals, like vegetables, consist of a few elementary principles; which, by combination in various proportions, give rise to their numerous varieties.

Carbon, oxygen, hydrogen, and nitrogen, are the principal ultimate elements of animal matter. Phosphorus, sulphur, lime, &c. are, however, often contained in it. The presence of *nitrogen* constitutes the most striking peculiarity of animal, compared with vegetable bodies; but as some vegetables contain nitrogen, so there are also certain animal principles, into the composition of which it does not enter.

The immediate materials of animals are very few in number, viz. Gelatine, Albumen, and Fibrine.

GELATINE.

Gelatine, or jelly, is the chief ingredient of skin and all the membranous parts of animals. It may be obtained from these substances, by means of boiling water, under the forms of glue, size, isinglass, &c.

It is soluble in water, and is capable of becoming a well known tremulous substance, by cooling, when the water is not too abundant, and liquifiable again on increasing its temperature. This last property distinguishes it from albumen, which becomes more solid by being heated.

It is precipitated in an insoluble form by tannin, and it is this action of tannin on gelatine that is the art of tanning leather. Leather can be produced, however, only from gelatine in a membranous state, the texture of the skin being necessary for the purposes of leather.

Glue is extracted from the skins of animals. Size is obtained either from the skin in its natural state, or from leather.

Isinglass is gelatine obtained from a species of fish, called sturgeon, and is known by the name of *ichthyocolla*. It usually comes from Russia.

ALBUMEN.

Albumen derives its name from the Latin language, and signifies the white of an egg, in which it exists abundantly and in its purest natural state. It is one of the principal constituents of most animal solids.

It is coagulable by heat, and is soluble in cold water previous to coagulation, but not afterwards.

It is, like fibrine, solid, white, insipid, inodorous, denser than water, and produces no action on vegetable colours.

resolved into the different elementary substances, such as carbon, carbonic acid, carburetted hydrogen, &c.; some of which are soluble in water, others float in the air, and in these different ways are presented to the roots and leaves of the *growing* vegetable. During the process of vegetation they are absorbed, and again appear in a new form.

The vegetable which to-day affords food for the ox or the fowl, is changed, and the same material substances, i. e. the oxygen, carbon, hydrogen, &c. appear in another kingdom of nature; they go to form a part of the *flesh* of the animals. And when the flesh of these animals is served up upon our tables, and used as food for man, it may again undergo another change, though perhaps a more honourable one,—may appear in the brawny muscle of the rich alderman, or help to round the contour of the neck of beauty.

The same *atoms*—say of oxygen, carbon, hydrogen, &c.—which six thousand years ago formed a part of the animal or vegetable kingdom in the Garden of Eden, may since that time have undergone a thousand changes—may have appeared in a thousand different forms; may at one time have formed a part of the pampered flesh of an eastern king, and at another of the beggar at his gate; may sometimes have appeared in the form of the beautiful *lily* or the useful *corn*, and at another in that of the deadly *nightshade.*

In the continual changes and transformations of these elementary substances, as here stated, though I see much that may tend to lower the dignity of man, permit me to say I see nothing which militates in the least against the final resurrection of the material body,

as taught in Revelation. It is no argument against this doctrine to say that the *same materials* have formed a part of a dozen different men, and therefore cannot again appear in all of them,—at least to one at all acquainted with the physiology of animals. For there is no one who has a smattering of this science of life (as physiology has justly been called), who is not aware that the *same* materials which form the boy of ten years, do not form the man of twenty or forty ; the particles of all the different organs of animals being continually absorbed and carried out of the body, and others afforded from the circulating blood constantly taking their place. It has been estimated, by those who have paid much attention to this subject, that the whole system in the human species is thus changed upon an average once in seven years. And yet the person who would contend that the man of forty was not the *same person* as when ten, we should look upon with pity rather than confront with argument.

Give some account of Mercury. What is Red Precipitate? Of what are Calomel and Corrosive Sublimate formed? What are their proper names?

Give some account of Platinum. Of Lead.

What are Litharge and Red Lead?

Of what is Acetate of Lead composed, and what is it generally called? What is White Lead?

LECTURE XVII.

ORGANIC CHEMISTRY.

What is Organic Chemistry?

Of what are Organized Bodies principally composed?

By what four circumstances may Organic Substances be said to be characterized?

What are the ultimate principles of Vegetables?

What are some of the proximate principles of Vegetables?

Give some description of Gum. The method of obtaining it. Its properties, &c. Of Sugar—Of Starch—Of Gluten—Of Extractive Matter—Of Tan—Of Colouring Matter—Of Wax—Of Fixed and Volatile Oils—Of Camphor—Of Resins—Of the Narcotic Principle—Of Vegetable Acids.

LECTURE XVIII.

ANIMAL CHEMISTRY.

What is the essential constituents of Animal Substances?

What constitutes a peculiarity of Animal, compared with Vegetable Bodies?

What are the immediate principles of Animals?

Give some account of Gelatine—Of Albumen—Of Fibrine. What do these form?

THE END.